BULLETIN 516 1946

GRADE YIELDS AND OVERRUN FROM INDIANA HARDWOOD SAWLOGS

Purdue University
AGRICULTURAL EXPERIMENT STATION
LAFAYETTE • INDIANA
In cooperation with
Central States Forest Experiment
Station Forest Service,
U. S. Department of Agriculture
Columbus, Ohio

PREFACE

This bulletin is representative of work by foresters to promote good forestry practices. It provides evidence that conservative cutting of our remaining sawtimber resources is vital to the permanence of the sawmilling industry. Responsibility for the maintenance of an adequate growing stock by controlling logging practices and by protecting from fire and pasturing is placed squarely before the landowner. What is shown to be a high-value log or tree, considering the owner's point of view, is likewise a highly profitable venture to the lumber manufacturer. Both the producer and the processor of sawlogs stand to gain, and society in general is benefitted by selective cutting of the timber resource.

Specifically, the bulletin treats of the amount and quality of lumber produced from Indiana hardwood sawlogs. This information is for the use of farmwoods owners as well as sawmill managers. A technique for appraising the value of standing sawtimber is suggested. While the present writing largely concerns the value of farmwoods timber, an investigation of the relative cost of converting the standing tree into lumber is anticipated at an early date.

The present study was financed jointly by the Purdue Agricultural Experiment Station and the Central States Forest Experiment Station of the U. S. Forest Service, under the Provisions of the Cooperative Farm Forestry Act (50 Stat. 188). Mr. R. C. Brundage of the Forestry Staff at Purdue University was originally assigned to the study at its inception on July 1, 1943, but he was obliged to divert his efforts to another venture of higher wartime priority early in 1944. The author hereby acknowledges the assistance of Mr. Brundage in the collection of all the field data upon which the investigation was based.

Acknowledgment is also due to Professor D. M. Matthews of the University of Michigan, Mr. L. F. Kellogg of the Central States Forest Experiment Station, Mr. L. I. Barrett of the U. S. Forest Service, Mr. C. H. Barnaby of Greencastle, Indiana, and my colleagues of the Forestry Department of Purdue University for their frank criticisms and helpful suggestions in reviewing the manuscript. My personal appreciation is likewise extended to the men associated with the 13 sawmills that provided the necessary study environment, without whose cooperation the study would not have been possible. These mills are listed in Appendix A.

It is sincerely hoped that this publication will prove of value to all of those who are interested in the promotion of better woods practices in Indiana and adjoining states.

Allyn M. Herrick

Purdue University, Lafayette
April 10, 1946

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Allyn M. Herrick

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I. INTRODUCTION

THERE IS NEED FOR GRADE YIELD AND OVERRUN INFORMATION

Sawlogs produced from Indiana farmwoods provide an important part of the cash income of many farmers. These same sawlogs likewise yield a profit to the mill man who converts them into lumber. There is some merchantable sawtimber on 50,000 farms in the state of Indiana and the operating sawmills in the state number around 1,000. Thus is evident the need for information concerning the volume and value of sawlogs, the primary product of the farmwoods and the sole source material of the lumber manufacturer. One aim of this publication is to further the mutual understanding of the farmer-producer and the manufacturer-consumer of sawlogs, through the presentation of unbiased facts concerning the quantity and quality of lumber which can be produced from various kinds of sawlogs.

WHY THE QUALITY AND QUANTITY OF LUMBER YIELDED BY SAWLOGS IS IMPORTANT

Both the grower and the user of sawlogs are vitally concerned with the potential lumber yield of those logs. The farmer should know how much volume and what grade of material he is selling, as well as the buyer should know what he is getting for his money. Unfortunately, many farmer-growers of sawtimber overvalue their trees and logs because they do not really know the worth of these trees or logs. Similarly, it is often true that timber buyers buy too cheaply. The farmer should be able to set and receive a fair value at the going price for his timber crop, hence a knowledge of volume and value is important. Logically enough, if a farmer is to demand premium prices for high-quality logs he must know how to grow those high-quality logs.

The sawmill operator, because of his experience, is better able than the farmer to judge the quality and determine the volumes of trees and logs. While the farmer seldom is aware of the importance of log size and log grade to the volume and value of the outturn, the log buyer recognizes these factors in all his dealings. Logs and standing timber are frequently priced according to the anticipated yield of No. 1 Common and better lumber[1] as estimated by the buyer. The buyer justifies this practice on the grounds that No. 2 Common lumber is sometimes and No. 3 Common grade is almost always worth less than it costs to produce. However, sawmill operators can well heed certain facts when buying logs or trees, especially if competition for scarce supplies is keen.

[1] See Appendix B for a brief description of hardwood lumber grades.

Most mill men agree that there is a certain minimum size of log on which they can make a profit. Grade yields and lumber values are very low from small logs, while the costs of processing are proportionately very high. The overrun[2] from small logs is considerable, but the board foot volume is mostly No. 3 Common lumber which is worth less than the cost of production. Yet many operators insist on manufacturing lumber from such logs, thinking that the overrun gives them a margin of profit.

The fact that an operator stays "in the black" is not evidence that he makes money on all sizes and types of logs. For instance, a "profit" of $800 may cover a loss of $200 in processing small logs. A profit of $1,000 might have been realized by cutting only the larger, profitable logs and leaving the smaller logs in the woods for growing stock, or for use other than as lumber. In short, Indiana sawmill operators should pay strict attention to the grade outturn of logs of various species, sizes and qualities and the excess of mill tally over log scale by log sizes.

The farmer and the lumberman can be in complete accord if each honestly faces the facts. No farm woods owner should allow a small tree to be cut for lumber if he realizes that an operator cannot afford to pay for it. No mill man should ever cut a small tree or haul a small log to his mill if he understands that it costs him more to manufacture into lumber than the lumber is worth. The small tree which is now worthless for the lumber it contains will shortly grow to a profitable size if left standing in the woods. Both the producer and the processor, then, stand to gain if only the larger trees in any woods are cut for sawlogs. The rapid increase in volume and value of smaller trees will yield periodic but permanent crops for the woods owner and at the same time they will provide an intermittent but enduring source of raw material for the lumber manufacturer.

HOW THE STUDY WAS CONDUCTED

Data for this study were obtained in 1943 and 1944. Lumber grade yields were measured at 13 sawmills located in northeastern and south-central Indiana. (See Figure 1.) Six of the mills used band headsaws while the other seven mills were of the circular type[3]. Many other mills were not used as study environments primarily because they were not manufacturing a normal percentage of four-quarter (one-inch) stock. Some mills were cutting thicker material for U. S. Navy orders; some were concentrating on gun stock flitches; some were producing thinner stock for crating war materials. In the interest of consistency, the output of the logs selected for this study was almost wholly of one-inch lumber. Such thicker or thinner stock as was sawed from these logs probably constituted a normal complement of their yield, so that the results of this study are not unduly influenced by wartime demands for outsize stock.

In any study of the yields of sawlogs it is necessary to recognize that they vary in quality. Several different hardwood log grading schemes have been devised. Many of them are so complicated that they are of little practical value. Quoting from a recent publication (*2*): "A set of grades inclusive enough to require little or no judgment in applying it would have to be so involved that only an expert could use it." With this thought in mind, a simple system of log grades for Indiana hardwood species was drawn up.

The tentative log grades disregard length except that they best apply to a 12-foot log standard. They are designed to work equally well on the

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[2] See page 27 for a definition.

[3] A list of the 13 cooperating mills appears in Appendix A.

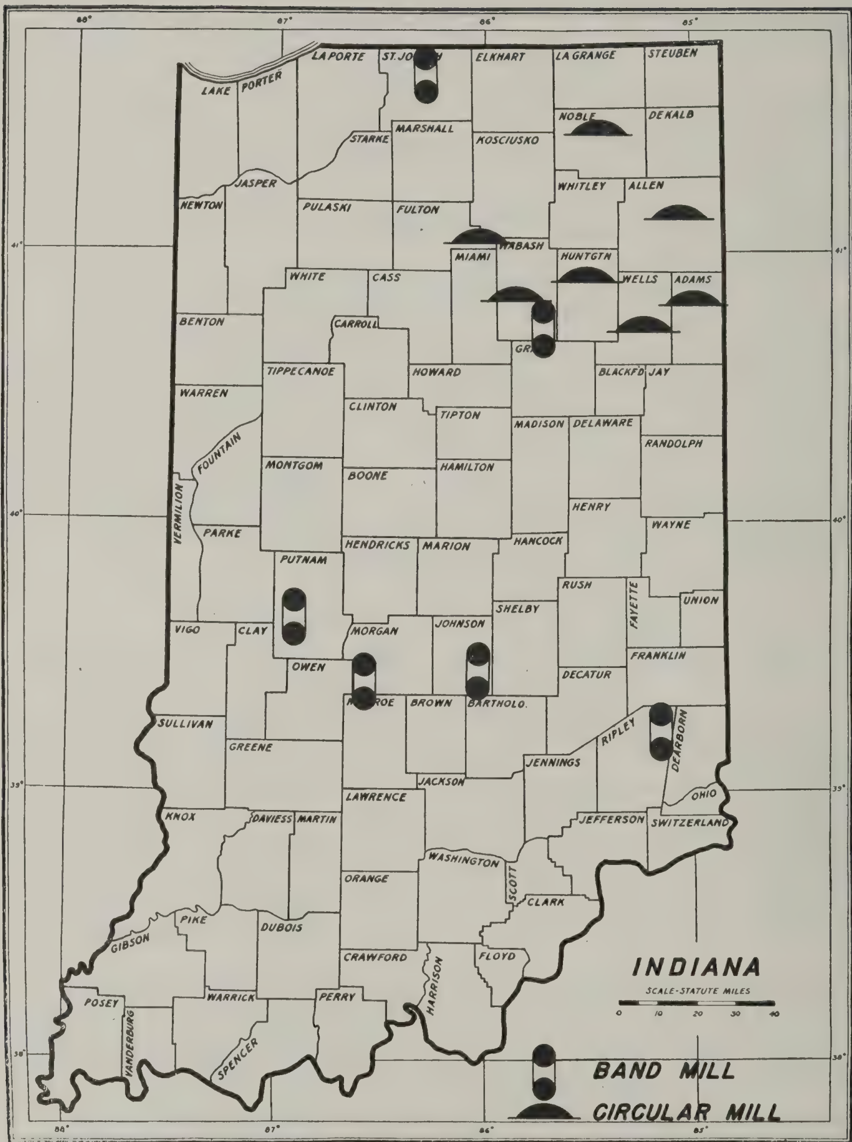

Figure 1. Location of the 13 cooperating sawmills.

standing tree or the cut log, because they require only an observation of "the three visible faces"[4]. Soundness, or the allowable percentage of deductible defect[5] for the various grades of logs is left solely to the judgment of the log grader. The grades are adaptations of "Northern Hardwood Log Grading Rules" as promulgated by the U. S. Forest Service (3), but simplified according to suggestions of J. W. Girard, formerly the Assistant Director of the U. S. Forest Survey. The four log grades with their specifications are as follows:

Prime—Practically (90 per cent) surface clear on three visible faces. Must be 16 inches or larger in d.i.b.[6]

No 1.—At least three-fourths (75 per cent) of length on three visible faces must be surface clear in one cutting[7]***. Must be at least 14 inches in d.i.b.***

No. 2—At least one-half (50 per cent) of length on three visible faces must be surface clear in two cuttings, neither of which is less than three feet long. Must be at least 10 inches in d.i.b.

No. 3—Will not meet No. 2 specifications.

Two-man crews were used in the collection of the grade recovery information. One member of the crew was stationed before the headsaw on the log deck or at the top of the jack chain for the purpose of grading, scaling and recording the logs before they were sawed. This man was responsible also for marking the log number on the last board sawed from each log before the board left the rear of the mill. The second member of the crew made a green chain lumber tally of the output of each log, recording board foot volumes by thickness and lumber grade. In seven of the mills the lumber was graded by qualified graders in accordance with the rules established by the National Hardwood Lumber Association; at the remaining mills, grading was the responsibility of the man making the lumber tally on the green chain. At nine of the mills a record was kept of the headsaw time per log.

A total of 861 logs, aggregating 124 MBM, lumber tally, was studied. Approximately four out of five of the total number of logs were sawed in band mills; these logs made up more than five-sixths of the total volume studied. (See Figure 2-A.) Five species or species groups[8] made up more than 80 percent of the logs and mill scale volume (Figure 2-B). They were beech, white elm, hard maple, red oak, and yellow poplar. Five additional species (ash, basswood, hickory, soft maple, and white oak) contributed appreciable numbers of logs to the study. Black and red gums, walnut, sycamore, and red elm were encountered less frequently. These last five species have been grouped herein as "others". Relative prevalence of the four previously described log grades is shown in Figure 2-C. Grade 2 logs were slightly more common than any other grade and contributed the greatest share of the volume. Although Prime logs were the smallest in number, the volume of Number 3 logs was less than that of any other grade. Each of the log grades, however, was well represented in the study.

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[4] A face is any one quarter of the surface of the log.

[5] A deductible defect is one that reduces the scale of a log. A defect of grade is one that reduces the quality of the lumber yield.

[6] Diameter inside bark at the small end of the log.

[7] A cutting is the length between surface indications of defect, whether sound or unsound.

[8] Botanical species are frequently grouped into commercial "species".

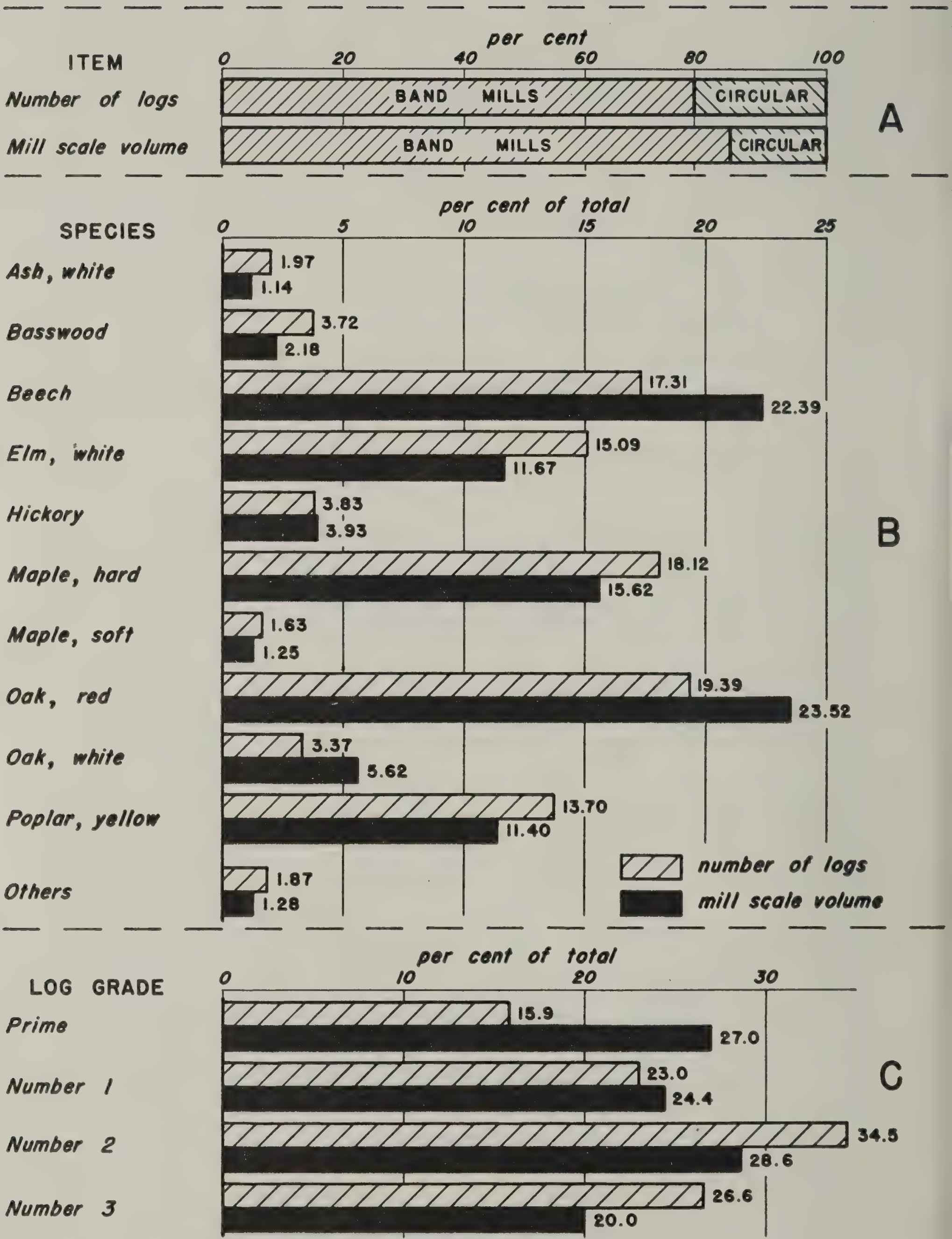


Figure 2. Distribution of the number of logs and mill scale volume according to: (A) type of mill, (B) species, and (C) log grade.

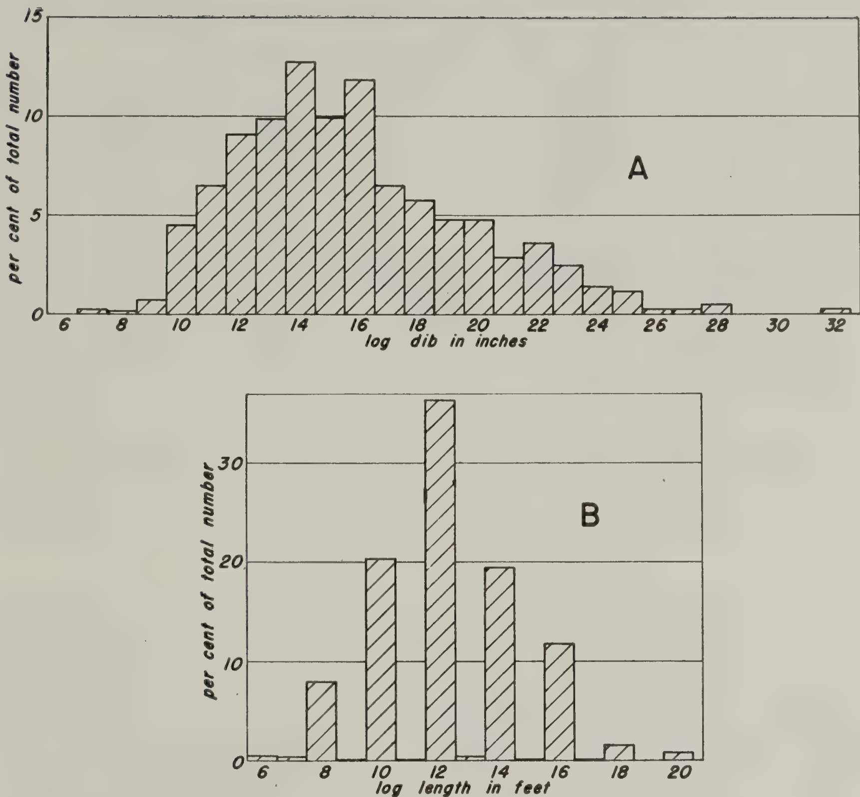


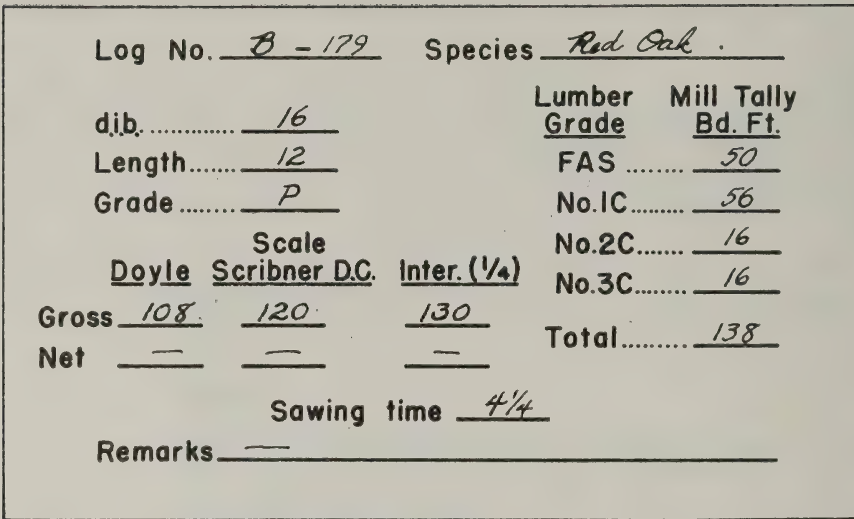
Figure 3. Distribution of the relative number of logs according to: (A) log d.i.b. and (B) log length.

Scaling diameters (small end d.i.b.) of the logs ranged from 7 to 32 inches, with 14-inch logs being more numerous than any other size. (See Figure 3-A.) Logs smaller than 10 inches and larger than 25 inches in d.i.b. were uncommon. More than one-third of the logs measured were 12-foot logs, but lengths ranged from 6 to 20 feet (Figure 3-B). Three of every four logs were 10, 12, or 14 feet long[9]. At least one log was included in each of the length categories except for the 19-foot class; 98.7 percent of the logs, however, were multiples of two feet in length.

Data for each log were transferred to an individual file card, as in Figure 4. These cards provided a record of the log number, species, diameter, length, grade, scale volume, sawing time, and lumber yield by grades, in addition to the reason for any deduction from the gross scale. Since logs were assigned key letters at each mill, as well as identifying numbers, it was possible to sort the cards on the basis of mills as well as according to the attributes of the logs themselves.

Log volumes as estimated by three scale rules (see page 23) were compared with the actual volumes of lumber cut from the several logs in both

[9] Scaling length. A nominal 12-foot log, for example, must have a trimming allowance of three or four inches in excess of the 12 feet. See page 24.



Log No. B - 179 Species Red Oak.

d.i.b. 16
Length 12
Grade P

	Doyle	Scale Scribner D.C.	Inter. (1/4)
Gross	108	120	130
Net	—	—	—

Lumber Grade	Mill Tally Bd. Ft.
FAS	50
No. 1C	56
No. 2C	16
No. 3C	16
Total	138

Sawing time 4¼

Remarks —

Figure 4. Individual log record card.

band and circular mills. Grade outturn was correlated with log quality evidenced by the four log grades. The effects of log size on the quantity and quality of yields and the costs of processing were studied.

In the following pages is a general discussion of the factors influencing the quality yield of sawlogs, followed by the specific grade recovery information resulting from this study. A "hardwood log quality index" is proposed. Overrun and log scales are discussed as they pertain to hardwood sawlogs, and some applications illustrative of the utility of overrun and grade yield data are presented. The final section deals with some implications of the results of the study as regards the management of farmwoods for the production of sawlogs.

II. THE QUALITY OF SAWLOG YIELDS

HARDWOOD LUMBER GRADES DETERMINE LOG VALUES

The more valuable species of hardwood lumber are usually graded in greater detail than less valuable species. Detailed grading systems extract a premium for high-quality lumber, while simple grading schemes tend to moderate the value differentials between good and poor lumber. Since most Indiana hardwoods may be considered specialty woods, they are ordinarily graded according to rather complex rules.

Besides the four more or less standard grades: "Firsts and Seconds", and "Numbers 1, 2, and 3 Common", some hardwood species are classified into as many as three additional grades. The "Selects" grade is typically grouped in the same category as No. 1 Common and is so considered in this study. Also the 2A and 2B, and 3A and 3B Common grades as are used for yellow poplar and sugar maple, respectively, are herein classed singly as No. 2 or No. 3 Common. The present study does not consider the Sound Wormy or Box grades. In short, only the four aforementioned basic lumber grades are used in this study.

LOG GRADES PURPORT TO ESTIMATE THE QUALITY OF LUMBER YIELDS

Most timber buyers emphatically argue that no list of log grading rules satisfactorily indicates lumber quality. They insist that only through long years of experience in logging and sawmilling can a person identify in trees and sawlogs their approximate output of lumber by grades. Yet some of these same buyers of timber and logs are required to denote quality on their volume estimate sheets. Some mark the entry for a given log as: "Good", "Common" or "Cull"; others designate log grades numerically as "1", "2", or "3". Consumers of large numbers of sawlogs are obliged to use a grading system in order to set their prices. Standard log grading rules are a necessity in such situations.

It is admitted that intricate systems of log grades are necessary for precise estimation of lumber grade recovery, but also that such systems are too complicated to be of more than academic value. As discussed in Part I, a log grading scheme must be simple to be useful.

The four simple log grades defined in Part I were designed to apply equally well to the standing tree or the cut sawlog. What they lack in accuracy they gain by ease of recognition. These grades, or some modification thereof, might well be adopted as standard throughout the central hardwoods area.

GRADE YIELDS MAY VARY WIDELY FOR DIFFERENT LOGS

Under common conditions of farmwoods stocking, trees tend to shed their lower branches. The dying-back of the lower branches is in direct response to shading from the upper part of the crowns. Other things being equal, a stand with a dense crown canopy will be relatively clean-boled; the stems will be relatively free from branches. On the other hand, if trees are grown without competition for light—grown in the open—they usually maintain a long live crown; they frequently have live branches all along the stem down to the ground.

All trees do not react to shading in the same manner. Certain species, like pin oak, tend to hold their branches more persistently than some other kinds of trees, yellow poplar, for example. The retention of branches may be either an inherent species characteristic or merely a consequence of too little shading from the side in the early life of the tree. The amount of shade received may be an inherent characteristic, of course, depending upon the requirements for establishment of the tree seedling. It is true, however, that different species exhibit striking variations in the persistence of branches along the lower portion of the tree bole.

Now the prevalence of branches along the stem of a tree—or if clean-boled, the length of time since the branches were dropped—are the two items which influence most the quality of lumber that the tree will yield. Knots in lumber are merely cross-sections of branches which were grown over by the body of a tree. Since lumber grades depend to a great extent upon the frequency and size of knots, it is clear that the relative persistence of branches, and if persistent, their relative size, are important factors controlling lumber grade recovery.

Significantly, the absence of branches along a tree bole means that some wood has been produced that is free from knots. Small trees are apt to have a thinner layer of knot-free wood than larger trees. Once a tree has established a clean bole, however, continued volume increment is necessarily high in quality. A thick layer of wood, unblemished by the presence of branches,

indicates that there will be a high percentage yield of high-grade lumber. Thus the size of a tree may be indirectly responsible for the quality of lumber it will produce.

Quality variations among species and grade fluctuations within species due to tree environment do not lend themselves to mathematical segregation. Although some systems of grading trees and logs attempt to recognize that certain groups of species yield characteristically poorer grades of lumber than certain other groups, it has already been stated that such systems are more accurate than practical. The simple log grading rules advocated and used in this study account for major variations in quality as are evidenced by surface indications; likewise they allow for grade variations due to log diameter. Log length is considered only indirectly, in that minimum lengths of clear cuttings are specified.

Logs cut to improper lengths are the bane of the sawmill operator. Aside from its effect on the volume of lumber, which is discussed later, careless cutting of felled trees into logs can result in lumber yields that are lower in quality than need be. Consider a 20-inch tree containing 24 feet of merchantable length, of which only the lowest 10 feet are free from surface indications of defect. If through incompetence or carelessness, the cutters reduce this tree to two 12-foot logs instead of a 10-foot butt log and a 14-foot top log, they may reduce the average grade recovery and value of lumber from this one tree as much as 10 percent. Consistent disregard for quality in log-making can easily cause as great a financial loss to both producer and processor as would a more glaring example of inefficiency.

Another factor influencing the quality of lumber that is produced from sawlogs is hidden defect. Hidden defects may be defined as those that possess no surface indications. Some of these defects are hidden in the tree and become evident in the cut sawlog, others do not show up until the log is actually sawed into lumber. Open (unsound) knots on a log frequently presage interior defects that reduce quality as well as the volume. Clearly, it is impossible to make an accurate appraisal of the effects of hidden defects upon either the volume or grade of lumber until after the lumber is manufactured. Extremely large, overmature trees are usually more defective than younger, thrifty trees. Certain species growing on certain types of soil or on certain exposures are characteristically defective, but experience alone must guide the appraisal of the extent of such hidden defects. A farmer-producer of sawlogs must therefore make allowance for the fact that black oak, for example, is quite commonly wormy and may not "saw out" as much high grade lumber as the exterior of the logs would suggest. Only the lumberman is capable of estimating the influence of such defects upon lumber quality.

VARIATIONS IN MILLING CREATE DIFFERENCES IN GRADE RECOVERY

Some sawmills strive to secure a maximum volume of output and pay little attention to its quality. It is the intent of other mills to obtain the highest average lumber grade recovery; the volume produced is considered secondary. The output of most mills represents a compromise between quality and quantity. It is a well-known fact that the two are complementary; as quality production goes up, volume production is sacrificed.

Many factors such as market conditions, the skill and efficiency of personnel, and the general state of repair of the sawmill machinery also cause variation in lumber grade yields. Any mill operator will try to take ad-

vantage of fluctuations in lumber prices by "cutting for grade" or "cutting for volume", whichever may seem to be more expedient. Highly skilled sawyers, edgermen and trimmermen typically produce better quality lumber and more of it than those less skillful. A large amount of degrade may occur because lumber is not cut "true to dimension." Variation in thickness of lumber, as well as uniform deviations from the intended thickness are common causes of reductions in quality. In short, the character of the milling operation may affect lumber grade production just as realistically as do differences in quality of the logs sawed.

DEVELOPMENT OF A HARDWOOD LOG QUALITY INDEX

Any problem concerning the recovery of the various grades of lumber from trees and logs is made more difficult by the necessity of recognizing the separate lumber grades. There is need for a single expression that will denote the average quality of a tree or log, as measured by the grades of lumber it will yield. The hardwood log quality index developed below is such an expression.

The yield of a log or tree is seldom composed of lumber of standard thickness. Although the percentage yields of the various lumber grades are not influenced markedly by the thickness of stock cut, it is true that lumber grade values increase appreciably with increases in thickness. Thus if one-inch FAS (Firsts and Seconds) white oak demands a price of $110 per MBM[10], two-inch stock of the same species and grade may be worth $16 more per MBM. All value differences between grades usually remain fairly uniform, however, regardless of the thickness of stock. For example, when No. 1 Common red oak lumber is selling for about 70 percent of the FAS price, this ratio holds good no matter for what thickness of lumber it is calculated.

Table 1 has been adapted from Amendment 11 to Maximum Price Regulation 155 to show prices for the four standard hardwood lumber grades and the ratios of the lower grade prices to those for FAS lumber. Nine species, comprising the bulk of the hardwoods cut in Indiana, are listed. (White elm an important species in this study, was not priced under this regulation.) The prices are for 4/4 (one-inch), plain-sawed lumber, only. At the bottom of Table 1 are shown the mean ratios for all nine species. Thus if species is disregarded, No. 1 Common lumber is worth 68.3 percent as much as FAS lumber, No. 2 Common, 47.5 percent as much, and No. 3 Common, only 27.7 percent of the FAS price.

The price ratios shown in Table 1 agree essentially with those in existence in an uncontrolled economy. Such data as have been published in prewar market reports indicate that the relative price structure was not materially altered by the imposition of lumber price controls. A canvass of Indiana sawmill operators likewise confirmed the assumption that in a free market, No. 1 Common lumber should yield 65 to 75 percent of the FAS price, No. 2 Common, 45 to 55 percent, and No. 3 Common, 25 to 35 percent. Hence the ratios in Table 1 were accepted as satisfactory expressions of grade-value differentials.

It is apparent that if the percentage yield of lumber grades for any tree or log is known, an index of the relative value of that tree or log may be easily computed from the aforementioned grade-value differentials. To the nearest ten per cent, the average ratios shown in Table 1 are: 70, 50, and 30,

[10] Thousand feet, board measure.

TABLE 1[1]. Plain-Sawed 4/4 Ceiling Prices from Amdt. 11, MPR 155 for Indiana Hardwood Species

Species	Price per thousand board feet				Ratio to FAS		
	FAS	No. 1C	No. 2C	No. 3C	No. 1C	No. 2C	No. 3C
	$	$	$	$	%	%	%
White ash	83.00	54.00	40.00	23.00	65.0	48.2	27.7
Basswood	84.00	60.00	43.00	23.00	71.4	51.2	27.4
Beech	84.50	57.50	41.00	28.50	68.0	48.5	33.7
Hickory	76.00	50.00	33.00	21.00	65.7	43.4	27.6
Hard maple	102.00	71.00	44.00	25.00	69.6	43.1	24.5
Soft maple	85.00	62.00	42.00	25.00	73.0	49.4	29.4
Red oak	83.00	61.00	44.00	25.00	73.5	53.0	30.1
White oak	110.00	65.00	44.00	25.00	59.1	40.0	22.7
Poplar	89.00	62.00	45.50	23.00	69.6	51.1	25.8
Average					68.3	47.5	27.7

[1] This table is presented solely for the purpose of illustrating the price differentials between lumber grades.

respectively, for Nos. 1, 2, and 3 Common lumber. A formula for a log quality index, which will denote relative value by considering relative lumber grade yields, may be written thus:

Quality index = (%FAS) + (0.7) (% No. 1C) + (0.5) (% No. 2C) + (0.3) (% No. 3C)

Table D-1 in the Appendix indicates the average percentage recoveries of the four lumber grades, by log diameter classes for Indiana hardwoods. Reference to this table shows that 20-inch logs of all grades, on the average, will yield: 25 percent of FAS, 40 percent of No. 1 Common, 15 percent of No. 2 Common, and 20 percent of No. 3 Common lumber. The average quality index for 20-inch logs of Indiana species may be computed as:

$$\begin{aligned} \textit{Quality index} &= (.25) + (0.7)(.40) + (0.5)(.15) + (0.3)(.20) \\ &= .25 + .280 + .075 + .060 \\ &= .665 \textit{ or } 66.5 \textit{ percent} \end{aligned}$$

That this single numerical criterion of log (or tree) quality and value is a serviceable measure for forester and lumberman alike, is demonstrated in Part V.

III. INDIANA HARDWOOD LUMBER GRADE RECOVERY

LOG GRADES OFFER A CLUE TO LUMBER GRADE YIELDS

Extent of the basic data which entered into the study of the recovery of various lumber grades has already been related in Part I. There, also the log grades used in this study for quality appraisal were defined. In the following pages, the grade outturn of lumber from Indiana hardwood species is expressed both in terms of the quality index suggested in Part II and as grade yields in percent of the total board foot volume.

That the four log grades are good expressions of variations in log quality is evidenced by the quality indexes of the average log in each grade. Irrespective of species or log size, the quality index figures for the four grades are as follows:

Log grade	*Quality index*
Prime	*74.36*
No. 1	*64.71*
No. 2	*58.57*
No. 3	*50.14*
All grades	*62.70*

The differences between the indexes corresponding to the several log grades are not equal in magnitude yet they are sufficiently large in each case to cause the various grades to be distinctive. If the outturn of a run of logs were composed of 25 percent each of the four lumber grades, the quality index would be 62.50. The average quality index is 62.70 for all logs included in this study.

Figure 5 illustrates the lumber grade production by log grades, for all species and separately for the five species which constituted the bulk of the volume studied. This figure has been produced from Table 2 which shows the percentage recovery of the various lumber grades by species, as actually calculated from the field data. Reference to Figure 5 shows that for all species, an increase in log grade from "No. 3" towards "Prime" effects:

(1) A progressive increase in the outturn of Firsts and Seconds lumber,

(2) A progressive decrease in the yield of Nos. 2 and 3 Common lumber, and

(3) No material change in the recovery of No. 1 Common lumber[11].

For the combined log grades, Figure 5 shows also that the logs included in this study yielded nearly equal percentages of the three lumber grades other than No. 1 Common, while more than one-third of the total volume produced was of this latter grade.

LOG GRADES ACCOUNT FOR MANY SPECIES VARIATIONS

Examination of the graphs for the five species shown separately in Figure 5 suggests that the grade recovery from red oak averaged higher than from any of the four other species. More than 65 percent of the red oak volume cut was No. 1 Common or better. Rating of the other species according to their quality yields is not easy, however, from Figure 5 alone. Sugar maple, with almost a 60 percent yield of No. 1 Common and better is difficult to rate in comparison with elm, which showed a higher yield of FAS lumber. Yellow poplar yielded a significantly lower percentage of 3 Common material[12], but the effect of this circumstance upon the average quality of lumber produced is difficult to appraise because the inclusion of the Selects grade with No. 1 Common likewise caused a relatively low recovery of FAS lumber for this species.

By the use of the quality index it is possible to rank the species according to their average lumber yields. It should be emphasized that neither quality index figures nor the graphs of Figure 5 are strictly comparable among species because of inconsistencies in log size. (See Table 3, page 28.) Large logs may be expected to show better quality yields than small logs, so some of

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[11] However, for the five principal species the yield of this grade falls off in Grade 3 logs.

[12] Poplar lumber was graded as 2A and 2B; the latter classification would include some of the otherwise No. 3 Common lumber. See page 10.

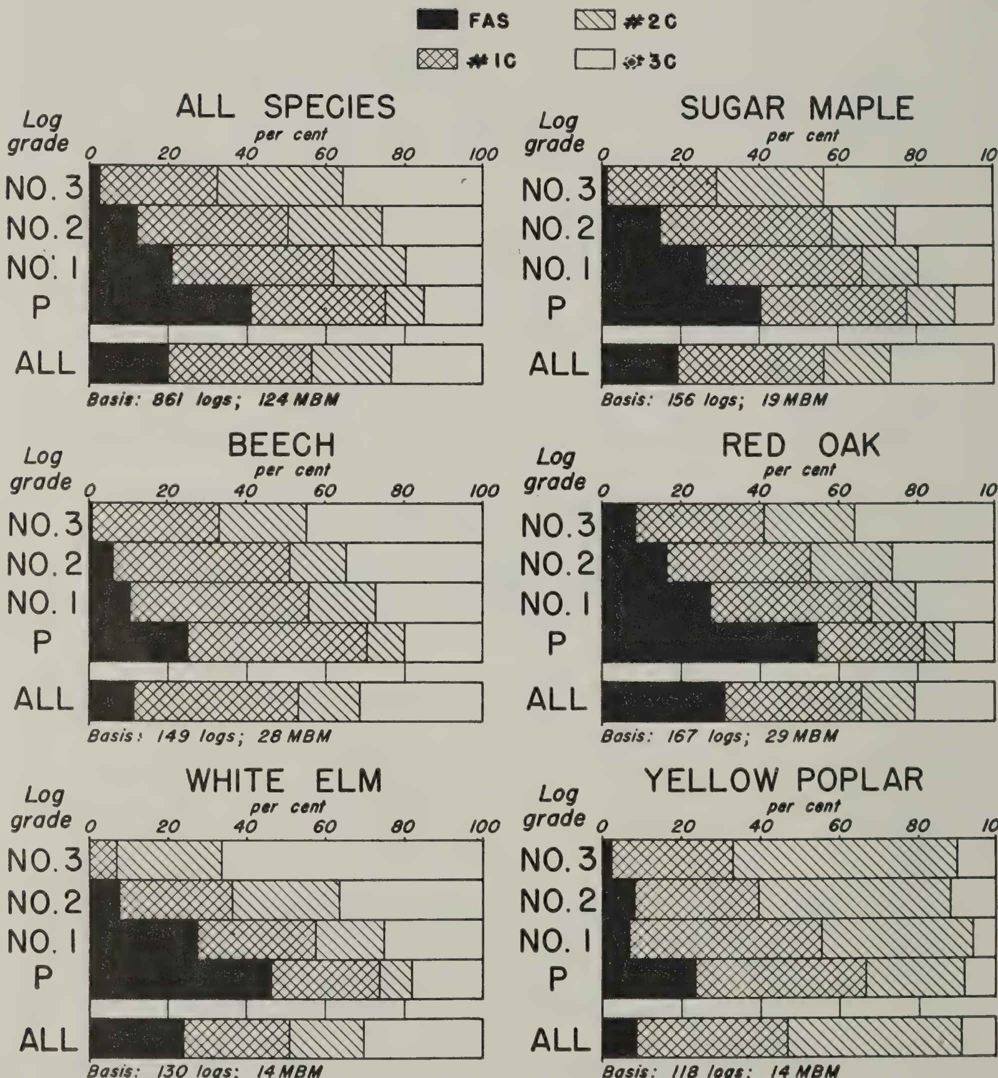


Figure 5. Lumber grade production by log grades and species.

TABLE 2. *Lumber Grade Recovery in Percent by Species and Log Grade*

Log grade	Lbr. grade	White ash	Bass wood	Beech	White elm	Hickory	Sugar maple	Soft maple	Red oak	White oak	Yellow poplar	All species
Prime	FAS	64.8	...	25.3	46.2	13.2	40.5	44.6	54.7	61.8	23.4	41.0
	No. 1C	20.3	...	45.5	27.5	38.8	37.2	37.7	27.5	21.1	43.3	34.2
	No. 2C	10.4	...	9.4	8.3	26.2	7.2	1.7	7.4	5.7	25.0	9.9
	No. 3C	4.5	...	19.7	18.0	21.8	15.1	16.0	10.4	11.4	8.3	14.9
No. 1	FAS	0.0	9.0	10.8	27.4	18.3	26.5	23.2	27.8	21.5	6.9	20.9
	No. 1C	60.7	43.7	45.2	30.0	39.7	39.8	34.1	41.0	57.6	48.7	41.0
	No. 2C	17.0	35.4	17.1	17.4	15.1	14.3	22.3	11.2	3 5	38.3	18.4
	No. 3C	22.3	11.9	26.9	25.2	26.9	19.4	20.4	20.0	17.4	6.1	19.7
No. 2	FAS	16.3	3.8	6.4	7.7	10.9	14.9	7.8	16.6	30.0	7.9	12.1
	No. 1C	37.2	33.6	44.8	28.8	23.8	43.8	39.4	36.6	53.8	31.7	38.4
	No. 2C	24.2	47.7	14.4	27.0	31.6	16.1	29.9	20.8	6.6	48.7	23.7
	No. 3C	22.3	14.9	34.4	36.5	33.7	25.2	22.9	26.0	9.6	11.7	25.8
No. 3	FAS	17.9	1.3	1.0	0.0	1.6	1.5	0.0	8.5	0.0	2.3	2.6
	No. 1C	28.8	20.6	32.2	6.9	28.6	27.7	5.1	32.9	54.6	30.6	30.0
	No. 2C	11.9	52.6	23.3	26.8	30.2	27.3	77.7	23.0	25.8	57.1	31.6
	No. 3C	41.4	25.5	43.5	66.3	39.6	43.5	17.2	35.6	19.6	10.0	35.8
All	FAS	30.7	4.2	11.7	24.0	12.8	19.3	18.1	31.6	35.6	8.4	20.2
	No. 1C	31.8	31.2	41.7	26.9	33.8	37.3	28.7	34.5	42.1	38.4	36.3
	No. 2C	16.9	46.4	15.6	18.8	24.7	16.9	33.7	13.7	9.7	44.2	20.2
	No. 3C	20.6	18.2	31.0	30.3	28.7	26.5	19.5	20.2	12.6	9.0	23.3
Basis in number of logs and board feet												
	Logs	17	32	149	130	33	156	14	167	29	118	861
	bd. ft.	1418	2703	27,794	14,477	4872	19,378	1545	29,183	6978	14,158	124,196

the variations here noted are due in part to log size, not species. Similarly, the relative frequency of the various grades of log influences the average lumber yield for the different species. The percentages of the total volume cut in each log grade for the five principal species are:

Species	Log grade				Basis
	Prime	No. 1	No. 2	No. 3	(MBM)
Beech	32.3	14.9	26.2	26.6	27.8
White elm	30.4	26.4	35.2	8.0	14.5
Sugar maple	18.3	28.6	26.8	26.3	19.4
Red Oak	33.2	30.2	24.4	12.2	29.2
Yellow poplar	14.1	31.3	29.7	24.9	14.2

Because the better grades of log should yield lumber that is higher in average quality than the poorer log grades, variations in grade yield that are apparently due to species are in part the effects of log quality. In fact, log grades account for many differences among species that are of a silvicultural nature.

For the five species shown in Figure 5, the quality indexes are:

Red oak	68.66
Sugar maple	61.81
White elm	61.32
Yellow poplar	60.08
Beech	57.99

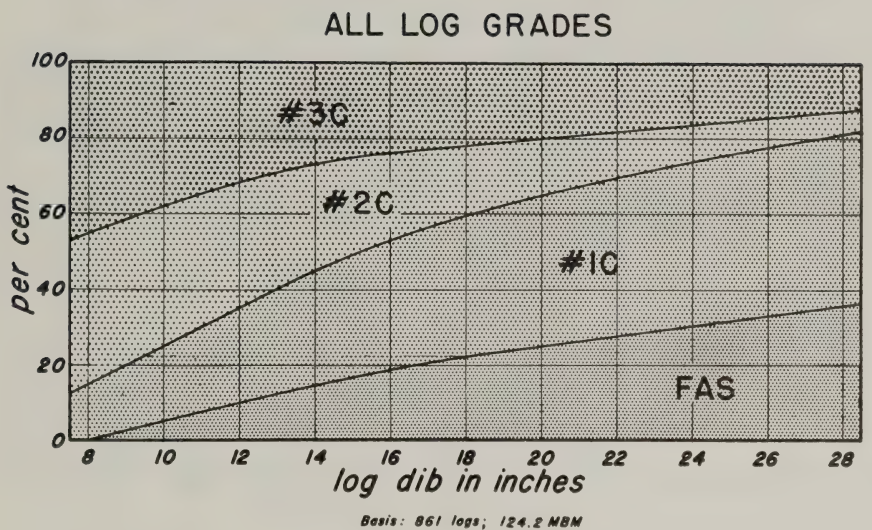
Red oak yielded significantly high quality lumber; the beech logs turned out the lowest average grades. Although the beech logs were larger in d.i.b. than those of the other principal species, the red oak logs were of a better grade, on the average, than those of the other four species. The logs of sugar maple and yellow poplar were of exactly the same average diameter (14.6 inches), yet because maple logs were of a slightly higher grade than were the poplar logs, the former yielded a slightly higher quality index. Even though the logs of white elm averaged one-half inch smaller in d.i.b. than yellow poplar, nearly 57 percent of the elm volume was sawed from No. 1 and Prime logs while only 45 percent of the poplar lumber came from logs this good. The quality index for elm was higher than that for poplar in spite of the fact that the poplar logs were the larger. These facts seem to indicate, then, that in the broader aspects:

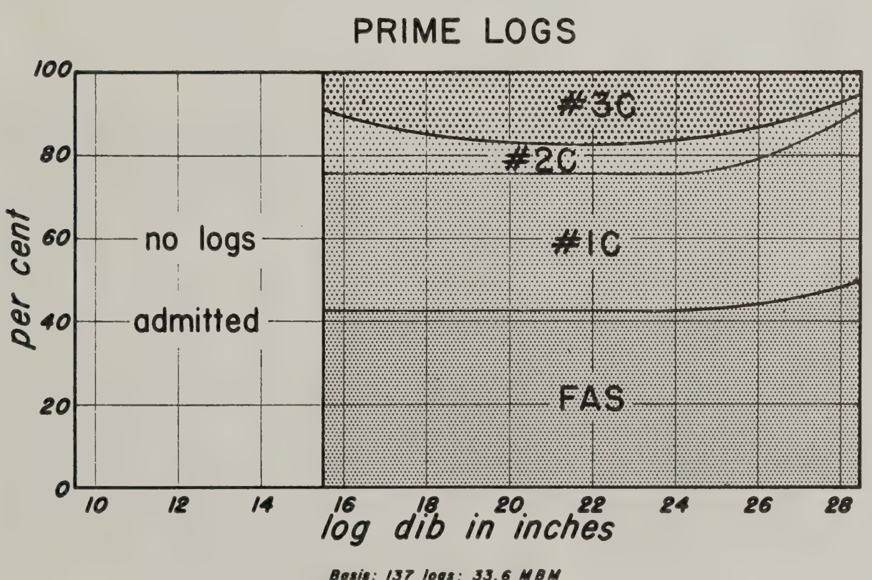
(1) Log grade is superior to log size as an index of lumber grade yields, and

(2) Species characteristics do not influence lumber grade yields markedly so long as logs are segregated by log grades.

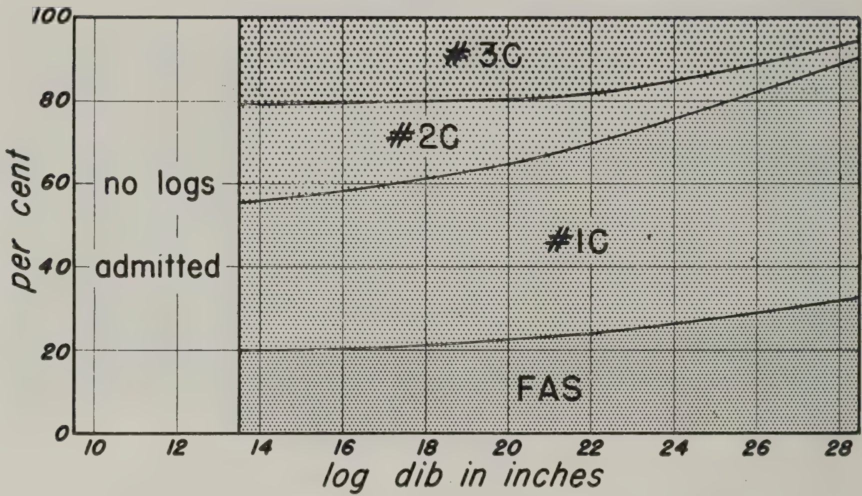
LOG SIZE IS A DIRECT INDICATION OF THE QUALITY OF YIELD

Figure 6 expresses graphically the rise in the quality of lumber with increasing log diameters. Grade recovery is shown by log grades as well as for all grades of logs combined. If log grades are disregarded, it may be noted in Figure 6 that more than 80 percent of the volume of 8-inch logs is


ALL LOG GRADES
100
80
60
40
20
0
per cent
#3C
#2C
#1C
FAS
8
10
12
14
16
18
20
22
24
26
28
log dib in inches
Basis: 861 logs; 124.2 MBM

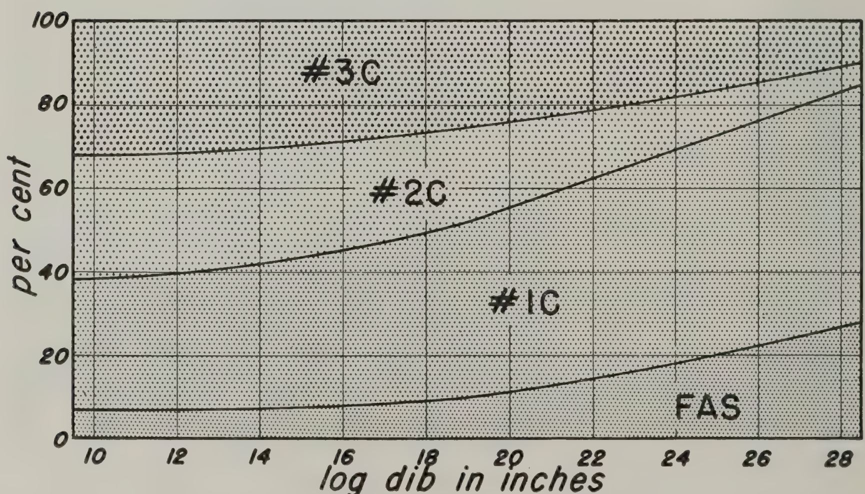

PRIME LOGS
100
80
60
40
20
0
per cent
no logs
admitted
#3C
#2C
#1C
FAS
10
12
14
16
18
20
22
24
26
28
log dib in inches
Basis: 137 logs; 33.6 MBM

GRADE 1 LOGS



Basis: 198 logs; 30.3 MBM

GRADE 2 LOGS



Basis: 297 logs; 35.4 MBM

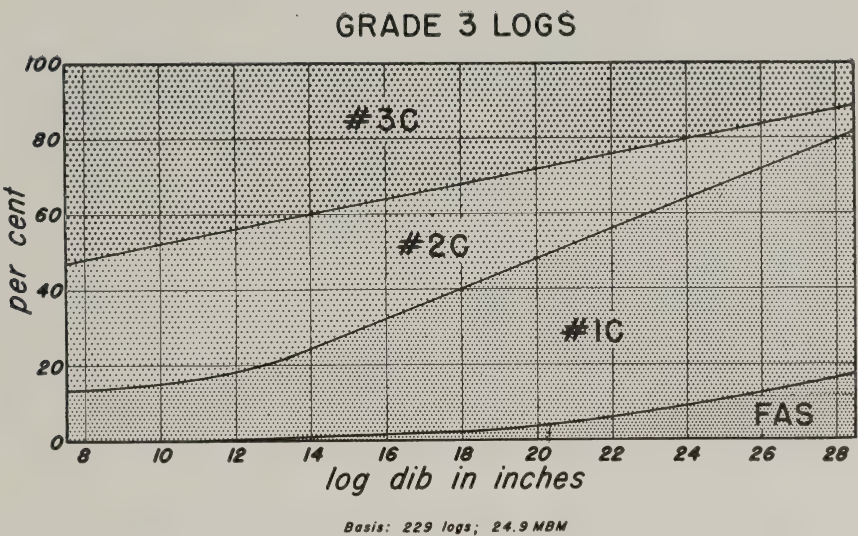


Figure 6. Lumber grade production by log diameters and log grades.

composed of the lower two lumber grades, whereas more than 80 percent of the lumber cut from 28-inch logs is No. 1 Common or better in grade. The quality increase due to log diameter is most pronounced up to a d.i.b. of approximately 16 inches; thereafter grade yields improve only moderately with increases in log size. If larger (than 28-inch) logs were included in this study, it is likely that they would show a falling off in quality, since such logs are frequently defective.

Further examination of Figure 6 is enlightening. The quality of lumber which Prime logs produce, is not markedly affected by log size. That is to say, 28-inch logs of this grade do not yield lumber of appreciably higher quality, on a relative basis, than 16-inch logs. In the poorer log grades, however, log d.i.b. exerts more influence on the grade recoveries. The comparatively horizontal lumber grade trends characteristic of Prime logs, begin to acquire a definite slope for grade No. 1 logs and become progressively steeper as log quality drops through grade No. 2 to No. 3. Figure 6 appears as Table D-1 in the Appendix.

THE QUALITY INDEX RELATES TO STUMPAGE AND LOG VALUES

The relation of log quality index to log d.i.b. is shown in Figure 7, one curve for each of the four log grades. As in Figure 6, the Prime grade of logs may be seen to yield an essentially constant lumber quality regardless of log size; as log quality decreases, log d.i.b. has an increasing influence upon grade yields.

Figure 7 is of importance because it shows the relative mill run value of lumber yielded by the various log grades for any size of log. Thus, lumber from 16-inch grade No. 3 logs has a quality index of about 50 percent and is

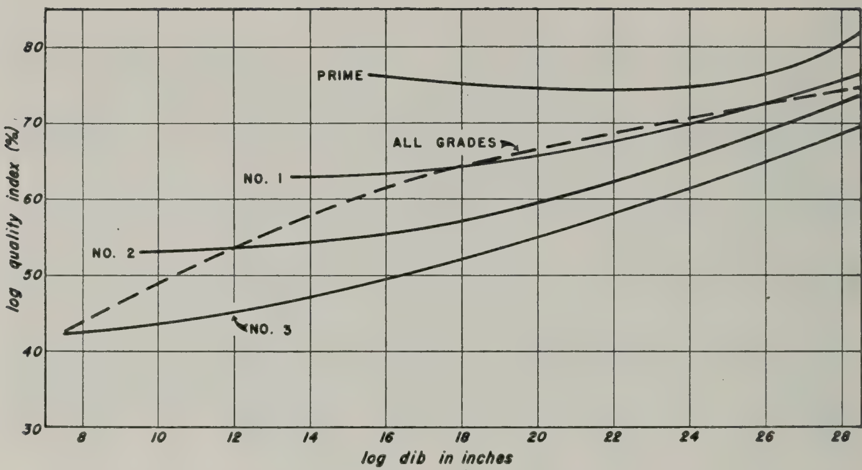


Figure 7. Relation of log quality index to log diameter and log grade.

worth only two-thirds as much as lumber from Prime logs of the same size, which have a quality index of approximately 75 percent. Assuming that logging and milling costs per unit volume are essentially the same for No. 3 as for Prime logs of any given size[13], the value of the logs themselves would be still more different. If for instance, the output of Prime logs were worth $60 per MBM and that of No. 3 logs only $40, a common cost of $30 per MBM for processing would make the Prime logs worth three times as much as the No. 3 logs ($30 versus $10) on the stump.

The log quality index, then, is a medium for estimating log values or stumpage prices. A tally of logs by diameter and grade will allow the estimation of the quality indexes from Figure 7, or its numerical equivalent, Table D-2, in the Appendix. These indexes when multiplied by the selling price of FAS lumber of the species involved will show the mill run value of the lumber which can be sawed from the logs. Illustrated in Part V is the use of grade recovery data and the quality index for the appraisal of standing timber.

IV. LOG SCALES AND INDIANA HARDWOOD OVERRUN

FACTORS AFFECTING THE QUANTITY OF SAWLOG YIELDS

There are two general classes of waste that are incurred when sawlogs are converted into lumber. The more important type of waste is that due to the saw kerf. Slabs and edgings comprise the second class of waste material. Because orders dictate the sizes to be sawed from a log, the amount of sawdust, slabs, and edgings varies and this influences the volume recovered. It will be shown later that sawmill equipment and the skill and practices of operators vary. These factors affect yield. The volume loss in both hidden and visible defects is difficult to ascertain with high precision, hence errors

[13] Actually a low grade log probably costs more to saw into lumber than a better log because it requires more turns on the carriage.

enter into log scaling. Finally, taper varies widely from place to place, from tree to tree, and from log to log within the same tree. For these reasons the determination of the probable lumber yield of a log—log scaling—is a matter of approximation rather than precise prediction. Accuracy depends upon a high degree of skill in applying a local knowledge of mill practice, defects, and products sawed.

ESTIMATES OF LOG VOLUMES BY MEANS OF LOG RULES

A tabular statement of the estimated yield in lumber of logs of various dimensions is called a ***log rule***. The Doyle log rule, over a century old, is more generally used in Indiana than any other rule. The Scribner log rule is no longer in common use in Indiana, although the Doyle values often appear in published form as the "Scribner log rule". An adaptation of the Scribner, called the "Scribner Decimal C log rule", is a rule officially used by the United States Forest Service. For scientific investigations foresters frequently use the International (¼-inch kerf) log rule because this rule is supposed to give a more accurate estimate of the lumber yield of a log than others. Whereas all log rules purport to show the contents of logs in terms of one-inch lumber and are uniform in this respect, only the International rule (of the three named above) gives consideration to the taper in a log. The International rule allows one-half inch for taper in each four feet of log length, while the other rules treat all logs as though they were cylindrical.

The Doyle, Scribner Decimal C, and International (¼-inch kerf) log rules are shown in Appendix B. The three broken-line curves in Figure 8 are graphic representations of the three rules, for 12-foot logs. The vertical bars and the solid-line curve in Figure 8 represent the actual board-foot yields, by log diameters, of all 12-foot logs cut by band mills which were included in this study. Several characteristic features of the log rules are apparent upon examining Figure 8. The International rule shows higher volume estimates than the other two rules for logs less than 26 inches in diameter. The values of this rule, for 14 to 17 inch logs, are very closely approximated by the actual yields of the logs, but for other sizes the rule underestimates the mill scale by varying amounts. As compared with the mill tally graph, the Doyle rule gives the lowest, but the most consistent estimates of log volumes. Addition of 30 board feet to the scale by the Doyle rule would produce volumes very similar to the actual mill tally figures.

Consistency in a log rule is fully as important as accuracy in predicting the outturn of a log. Because of variations among the logs themselves and because of variations among the lumber manufacturing processes, however, no log rule can be expected to give an exact estimate of the contents of all logs. Factors which influence the accuracy and consistency of log rules are discussed at some length below.

VARIATIONS AMONG LOGS WHICH AFFECT THEIR YIELDS OF LUMBER

The diameter of a log, inside of the bark at the smaller end, is the most important log dimension from a volumetric standpoint. This is known as the "scaling diameter" because it is the diameter to which any log rule applies. The volume of a log varies approximately as the square of the log diameter, that is, a 20-inch log should produce about four times as much lumber as a log 10 inches in diameter, a 30-inch log, about nine times as much. Actually, doubling the diameter of a log more than quadruples its volume, because the ratio of board feet to cubic feet is higher for the larger log.

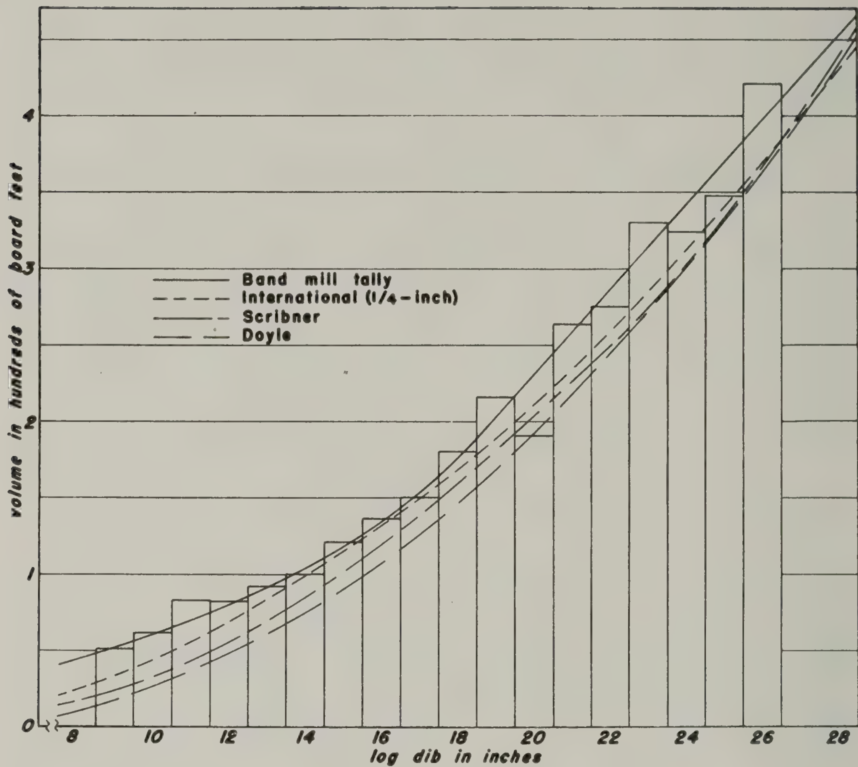


Figure 8. Graphic representation of three log rules and the corresponding band mill tally for 12-foot logs.

In theory, and according to the common log rules, log volume is directly proportional to log length. Thus a 16-foot log of any diameter is scaled as though it contains twice the amount of lumber in an 8-foot log of the same diameter. Due to the fact that logs have more or less of a taper, a long log will actually yield somewhat more than twice the volume of lumber which can be cut from a similar log only half as long. The International log rule, which allows for taper, takes this fact into account, whereas the Scribner D.C. and the Doyle rules do not. Hence the International is more accurate in estimating the volumes of long logs than are the other two rules.

Actually a log must be cut so that it is longer than the nominal or scaling length by about three or four inches. This extra length is called a "trimming allowance" and is necessary because the ends of logs are seldom cut exactly "square" with the longitudinal axis of the log. If through ignorance or carelessness, a log is cut without any trimming allowance, a loss of volume is almost certain to result. In squaring up the ends of the boards sawed from such a log their length will doubtless be reduced to the next lower foot, hence it is a common practice to scale a log that lacks a trimming allowance, as though it were shorter by a foot than the actual length.

Generally speaking then, log scaling by any rule considers variations in diameter and length of log. No log rule makes allowance for ***variations*** in taper, although the International makes allowance for a ***standard*** taper of one-half inch in four feet of length. Variations in sawlog tapers are attributable to variations in tree form. Although growing conditions exert a great influence upon the relative amounts of taper in trees, that subject is beyond the realm of this discussion. Of importance here is the fact that tree taper follows a somewhat standard pattern. It may be stated generally that the section of a tree stem that is near the ground and the portion of the stem just above the lower limit of the live crown exhibit a greater amount of taper than does the remainder of the stem. Thus butt logs and top logs will usually taper more rapidly, per unit of log length, than logs cut from the middle bole.

Reference was made earlier to the fact that the International (¼-inch kerf) log rule values closely approximated the actual yields of logs from 14 to 17 inches in diameter, in this study. The International rule, which allows for a "normal" taper of one inch in eight feet of length, underestimates the yield of logs smaller than 14 inches and larger than 17 inches d.i.b. (See Fig. 8.) Such logs are preponderantly top logs and butt logs, respectively, and their "excessive" taper[14] contributes to an excess of lumber over the amount shown in the rule. Hence, no log rule, even though it considers a "normal" amount of taper, can give precise estimates of lumber volumes because of characteristic and consistent deviations from "the normal" in the taper of logs.

Another cause of variability in lumber yields of logs is defective material. All log rules pretend to show the volumes of sound logs, only, and it is the responsibility of the person applying the log rule to allow for deductible defects. Important volumetric defects which are found in hardwood sawlogs are: heart or butt rot, cup or ring shake, frost cracks, fire scars and crookedness. As trees become overmature defects become more and more prevalent. Since as many as 20 percent of any run of hardwood logs may contain one or more deductible defects, the latter constitute an important cause of variability in sawlog yields. In order to eliminate inconsistencies in making allowances for deductible defects, however, only sound logs were used for the strictly volumetric phases of this study.

THE SAWMILL ITSELF INFLUENCES THE LUMBER CONTENT OF SAWLOGS

Fully as important as variations among the logs to be cut, are differences in processing those logs. That is to say, a given log sawed into lumber at a certain mill would probably yield a different volume of lumber were it to be processed at a different mill or under different conditions. Inconsistencies in sawmilling practice cause varying amounts of waste; therefore the lumber yields from identical logs may vary, due to this fact.

The milling equipment, particularly the head-rig, controls the output of any log to a certain extent. Due to the fact that band mills cut a narrower saw kerf, they realize a higher yield of volume from any size of log than do circular mills. Figure 9 compares the volume sawed from 12-foot logs of various diameters as cut in band mills with the volume realized from the same sized logs at circular mills. In this study the latter type of mill recovered only about 78 per cent as much lumber from the study logs as did the band

[14] Routine checks of the butt log of Indiana hardwood trees have shown that the average taper in the lowest 12 feet of merchantable length is 3.4 inches instead of the 1.5 inches allowed for in the International rule.

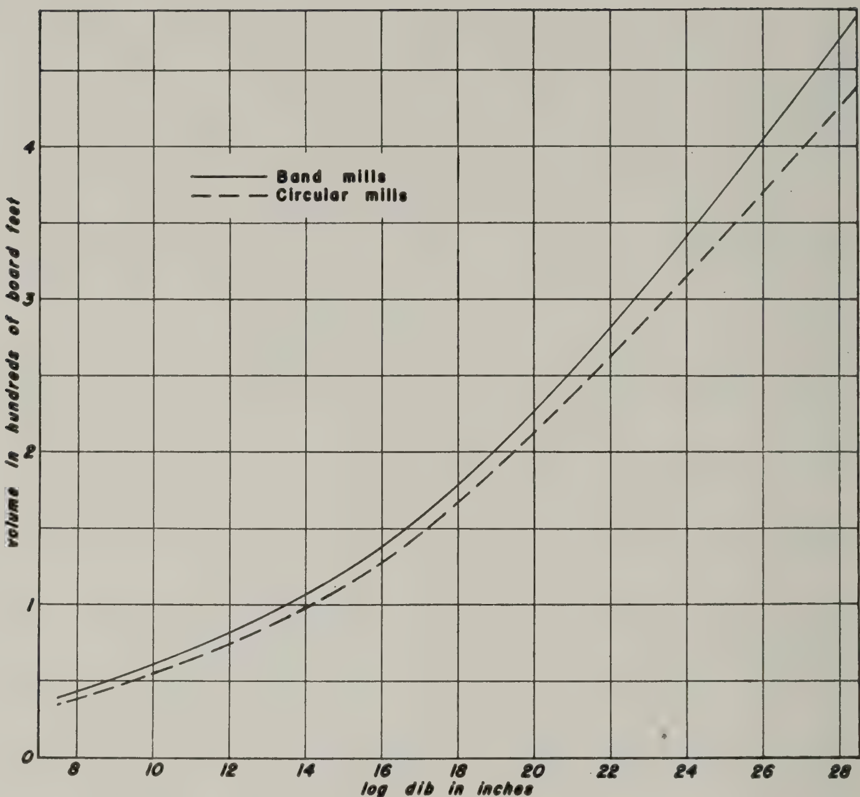


Figure 9. Mill tally from 12-foot logs.

mills. Tables E-1 and E-2 in the Appendix show the mill tally for band and circular mills, respectively.

Another manner in which sawmill machinery may influence lumber yields pertains to the general state of repair, or the operating precision of the mill. If the carriage or tracks are out of alignment, or the blocks are not in adjustment, stock is produced which is not "true" to dimension. Although this condition affects the grade yield primarily, it also reduces the volume of lumber produced to a certain extent. Wedge-shaped scrap inevitably results from inefficient milling equipment, over and above that created by the taper in a log.

Experience, skill and efficiency are attributes of labor which unquestionably affect the outturn of a log. The head-sawyer has the most apparent opportunity of minimizing waste, but the edgerman and trimmerman are also of great importance in attaining a maximum of volume production. Activities of the latter two men are generally aimed toward the production of the highest possible grades of lumber, yet they have many chances to boost the total lumber output in volume as well as in quality.

Other factors, indirectly associated with the milling environment, also influence lumber yields appreciably. Market conditions which call for close

utilization will increase the volume output of a mill through concerted efforts to save small pieces. Demands for thick stock which requires fewer saw cuts, likewise raise the production.

MILL TALLY MINUS LOG SCALE EQUALS OVERRUN

The preceding discussion has been set forth to show the difficulty of applying the board foot unit to material "in the round." It has been stated that, for many reasons, the board foot content of logs and trees cannot be determined absolutely before they are reduced to lumber. Thus the application of a log rule to a log merely provides an ***estimate*** of the board foot content. Such estimates of log volume, however accurate or erroneous they may be, are referred to as: board foot volume, ***log scale.*** Log tally, woods scale, etc., are synonymous terms. As a differentiating term, quantities of sawed lumber are called: board feet, ***mill tally.*** Mill scale, lumber tally, etc., mean the same as mill tally. Reasons for keeping these two types of volume separate are obvious.

Except in the rare instances when a log rule gives a precise estimate of the amount of lumber in a log, there is always a difference between board feet, mill tally, and board feet, log scale. If mill tally exceeds the log scale by any rule, the positive difference is called ***overrun;*** if overrun is negative, it is commonly called ***underrun.*** The usual practice has been to express overrun as a percentage of the log scale. A convenient formula for computing overrun in percent is:

$$\left(\frac{\text{Mill tally}}{\text{Log scale}} - 1\right) 100 = \%\ \text{overrun}$$

A flat percentage of overrun can be applied to total log scale in order to derive an approximation of the real lumber content. Treatment of overrun as a percentage of log scale is justifiable only so long as the figure is correct for the frequency of log diameters to which it is applied. As will be illustrated below, the percent of overrun varies greatly according to log size; a percentage for 14-inch logs will underestimate the actual lumber yield if it is used for logs averaging 12 inches in d.i.b. Actual overrun in board foot units will be considered later, in addition to percentage overrun. Logs are best sold on the basis of log scale, whereas lumber is sold "mill tally"; hence both the grower and the consumer of sawlogs must be concerned with overrun.

IN THE AGGREGATE, EACH SPECIES AND LOG RULE SHOWED A PERCENTAGE OVERRUN

The basis for the study of overrun is shown in Table 3. Only those logs which were free from external evidences of deductible defect or cull were included. Eighty-five percent of the total of 757 logs involved were of five species. Because of differences in the size of the average log, the overrun of the mill tally from any of the scale rules is not directly comparable among species. White oak, for example, shows a relatively low percentage overrun for any of the three log rules, but this is due in a large measure to the fact that the d.i.b. of the average log processed is greater than that of any other species. Average lengths are so similar that it is impossible to attribute variations in overrun among species to this factor. Of interest are the facts that the average overrun from the Doyle, Scribner D.C. and International rules approximated 25, 15, and 5 percent, respectively, and that the mill tally volumes exceeded the log scale volumes, in the aggregate, for each species and log rule.

TABLE 3. *Summary of Mill and Log Scale Volumes and Overrun for Indiana Hardwoods (Sound logs only)*

Species	No. of logs	Mean log dib. in.	Mean log length[1] ft.	Mill tally	Volume in board feet Doyle	D.C.	Int. ¼
Red oak	157	16.5	12.8	27,007.3	21,810	23,730	25,540
Beech	100	17.3	11.8	18,054.1	14,318	15,490	16,430
Sugar maple	146	14.6	12.6	17,699.5	13,910	15,700	17,435
Yellow poplar	116	14.6	12.4	13,761.8	10,695	12,070	13,430
White elm	125	14.1	11.5	13,682.7	10,548	12,010	13,150
White oak	26	19.8	12.9	6,429.2	5,720	5,950	6,260
Hickory	31	15.1	12.9	4,390.5	3,348	3,720	4,145
Basswood	30	13.3	11.3	2,745.3	1,969	2,280	2,590
Soft maple	12	13.8	12.0	1,419.8	902	1,030	1,180
White ash	14	12.8	10.0	1,135.5	760	880	975
Total	757	...	...	106,325.7	83,980	92,860	101,135
Average	...	15.4	12.3	....	.....	.....	......

[1] Scaling length (minus trimming allowance).

Species	Overrun in board feet Doyle	D.C.	Int. ¼	Overrun in percent Doyle	D.C.	Int. ¼	Board foot Overrun per log Doyle	D.C.	Int. ¼
Red oak	5,197	3,277	1,467	24.0	14.0	5.9	33.1	20.9	9.4
Beech	3,736	2,564	1,624	26.0	16 4	9.8	37.4	25.6	16.2
Sugar maple	3,790	2,000	265	27.3	12.7	1.6	26.0	13.7	1.8
Yellow poplar	3,067	1,692	332	28.6	14.1	2.4	26.4	14.6	2.9
White elm	2,135	1,673	533	29.6	13.8	4.0	17.1	13.4	4.3
White oak	709	479	169	12.3	8.1	2.7	27.2	18.4	6.5
Hickory	1,042	670	245	31.2	18.1	6 0	33.6	21.6	7.9
Basswod	776	465	155	39.3	20.3	6.0	25.9	15.5	5.2
Soft maple	518	390	240	57.4	27.8	20.3	43.1	32.5	20.0
White ash	376	256	161	48.0	27.8	15.3	26.8	18.3	11.5
Total	22,346	13,466	5,191	...	...	...	...	...	...
Average	.....	.....	....	26.6	14.6	4.9	29.5	17.8	6.8

PERCENTAGE OVERRUN VARIES GREATLY WITH LOG DIAMETER

Earlier in these pages it was pointed out that the type of sawmill—whether band or circular—is an important factor governing the amount of volume that is cut from a given log. Consequently the band sawmills were kept separate from the circular mills in the analysis of overrun. Although log length is a factor affecting overrun it has not warranted separate treatment herein. Figure 10 shows the percentage overrun trends for three log rules and the two types of mill; Tables E-3 and E-4 in the Appendix show numerical equivalents of Figure 10. Worthy of note is the fact that the International log rule yielded an underrun when applied to logs larger than 14 inches in diameter if cut at circular mills. None of the rules produced an underrun at band mills.

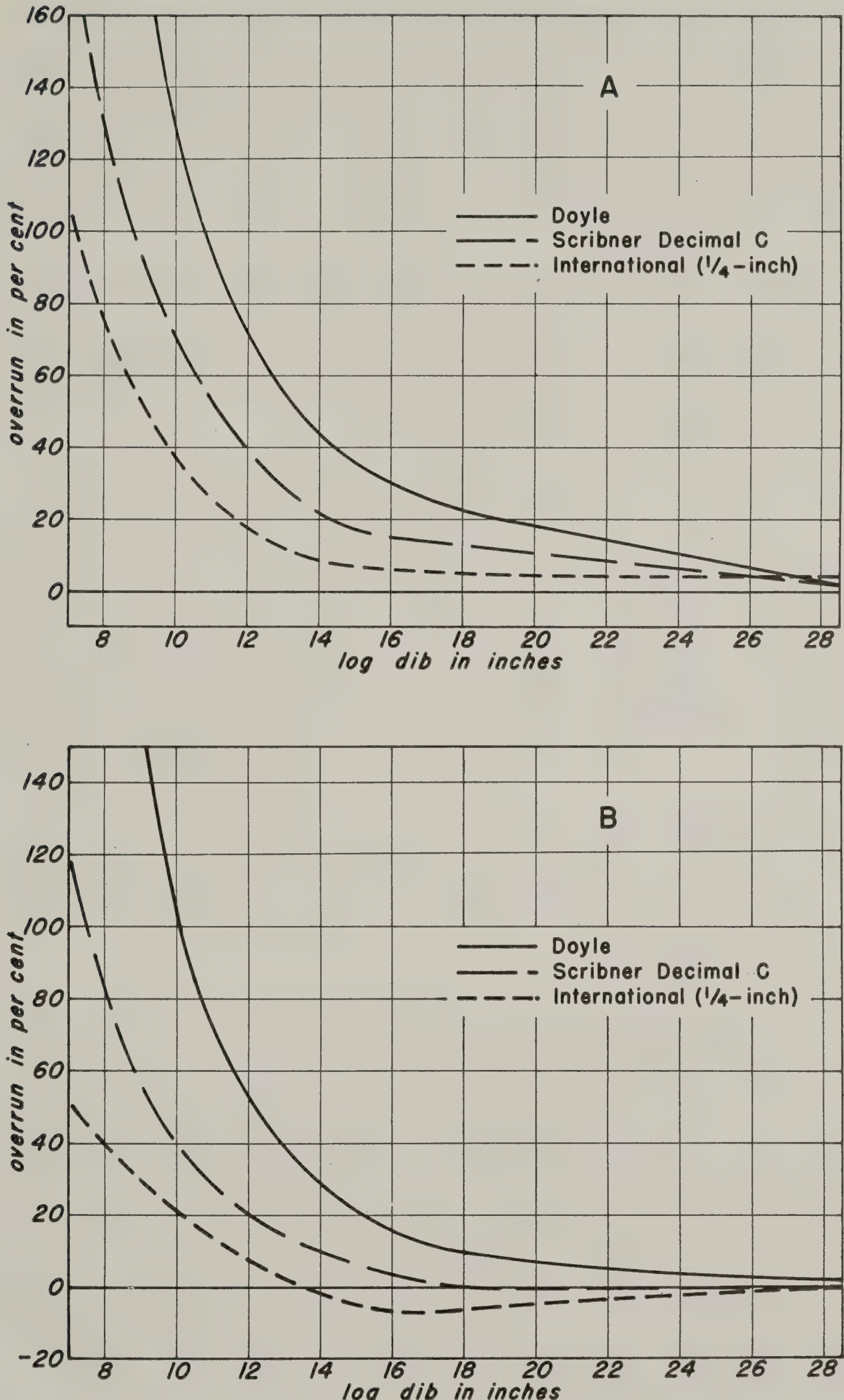


Figure 10. Percentage overrun from three log rules for (A) band mills and (B) circular mills.

It may be seen from Figure 10 that the International rule yielded less overrun than the other two rules, so from this standpoint it is the most accurate of the three rules. The Doyle rule, on the contrary, made the greatest over-estimate of volume. The trend lines for all three log rules show a definite dependence on log size, however. No matter what rule or what kind of mill was involved, small logs yielded a high percentage overrun whereas large logs yielded very little overrun, or sometimes an underrun. This makes difficult the use of percentage overrun data. A percentage applicable to one size of log is in error if applied to logs of a different size.

OVERRUN CAN WELL BE EXPRESSED IN BOARD FEET PER LOG

To avoid the complex relationships existing between percentage overrun and log diameter, overrun in board foot units is worthy of consideration. Trends of overrun, expressed in board feet per log, for both band and circular mills are shown in Figure 11 and in Tables E-4 and E-3 of the Appendix. These linear trends are dependent upon log diameter, but are much simpler functions of log size than are the trends of percentage overrun in Figure 10. The percentage trends and the board foot trends are not exactly comparable. The Scribner D.C. rule showed neither overrun nor underrun in percent at circular mills for logs more than 20 inches d.i.b. in Figure 10, yet the same rule indicated an underrun for these same sized logs when the board foot unit was used. The difference arises from the conditions imposed upon the data in the graphic analysis. In essence, however, Figures 10 and 11 may be considered interchangeable.

Since the trend of overrun in board feet is linear it is possible to describe the relationship between overrun and log diameter by means of a simple mathematical expression. Formulas that approximately define the six straight lines of Figure 11, when: Ov = the overrun in board feet and D = the log d.i.b. in inches, are as follows:

Band mills

Doyle	$Ov = 40 - D/2$
Scribner D.C.	$Ov = 29 - D/2$
International (¼-inch kerf)	$Ov = 24 - 4D/5$

Circular mills

Doyle	$Ov = 40 - 3D/2$
Scribner D.C.	$Ov = 30 - 3D/2$
International (¼-inch kerf)	$Ov = 16 - D$

These simple formulas are merely rules-of-thumb for determining the average board foot overrun to be expected from logs of various sizes. As such they may be used for directly converting log scale into an estimate of mill tally.

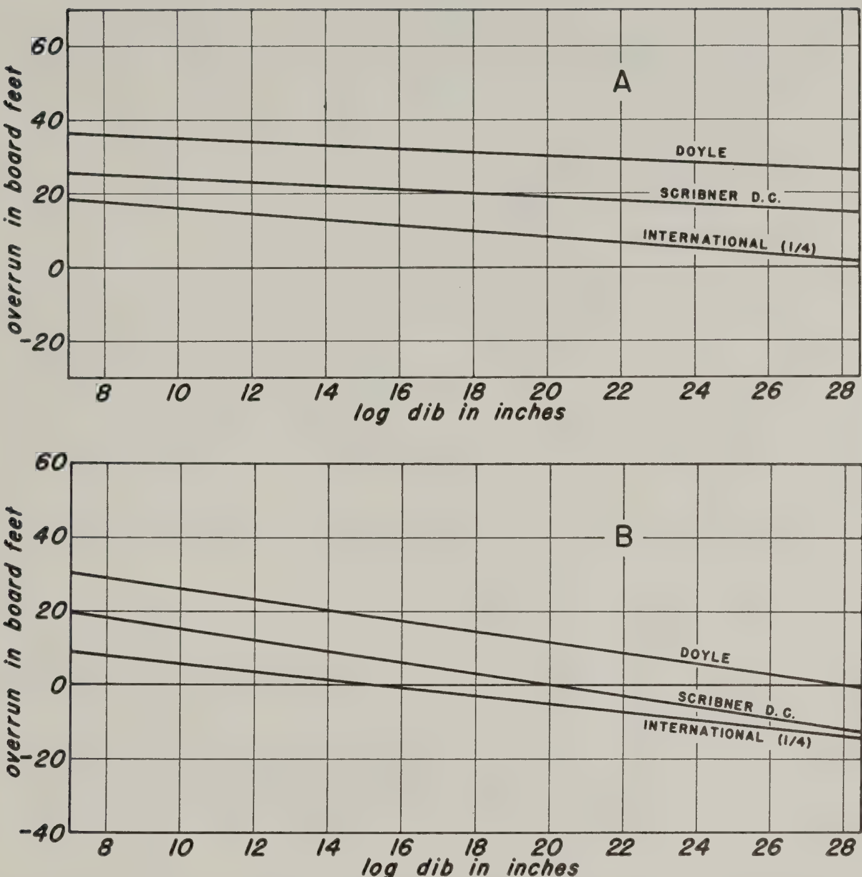


Figure 11. Board foot overrun from three log rules for (A) band mills and (B) circular mills.

V. APPRAISAL OF STUMPAGE VALUE

GRADE YIELD AND OVERRUN INFORMATION ARE USEFUL

The appraisal of stumpage value consists of deducting the estimated total costs of production from the estimated selling price of lumber produced. This fundamental relationship may be expressed by the simple formula:

Stumpage value = Selling price — Production costs.

A detailed analysis of logging and milling costs is not within the scope of this study, although an illustration of the use of cost data in estimating stumpage value is given below. The estimation of lumber values is, however, directly dependent upon a knowledge of lumber grade recoveries and overrun, consequently use is made herein of the information derived from this study. Methods of using the findings as shown in Parts III and IV and in the Appendix, are discussed at some length in the following pages.

HOW GRADE RECOVERIES MAY BEST BE PREDICTED

Grade yield information for hardwood sawlogs has been referred to in Part III and the Appendix. It is evident that lumber grade recoveries, either in terms of percentages or quality indexes, may be estimated by any one of three methods:

(1) From log sizes alone,

(2) From log grades alone, and

(3) From log sizes and log grades.

On page 18 it was intimated that the prediction of grade recovery by the use of log grades was more accurate than by the use of log sizes. The accuracy of a prediction based upon grades and sizes in combination should be still greater.

To test the relative accuracy of the three techniques for predicting grade yields, a sample of 100 logs was mechanically selected from all of the logs included in this study. The size and grade of these sample logs were applied to the grade recovery data derived from all of the logs. The estimation by log grades alone was made through use of the last column of Table D-1 in the Appendix. The same table was used for grade yield predictions by sizes alone, and by sizes in combination with log grades. The results of the test are given in Table 4.

The implications concerning accuracy in the prediction of grade yields are borne out in Table 4. As was expected the combined influence of log size and log grade produced a more accurate estimate than did either size or grade individually. Likewise log grades proved to be more nearly accurate than did log sizes. It is significant, however, that the three techniques were not markedly different in accuracy.

TABLE 4. Relative Accuracy of Lumber Grade Predictions by Three Different Methods (Based Upon 100 Logs)

Lumber Grade	Method		
	Log sizes	Log grades	Sizes and grades
	Aggregate percentage error		
FAS	+ 1.33	— 0.66	— 3.10
No. 1C	— 1.42	+ 3.12	+ 1.12
No. 2C	+17.31	+12.38	+13.94
No. 3C	—10.92	—12.19	— 8.69
Average	± 7.74	± 7.09	± 6.71

The yield of FAS and No. 1 Common lumber was estimated much more precisely than that of the two lower grades in each case. The maximum error among the estimates of lumber grades appeared in the No. 2 Common grade. Whereas log sizes yielded an error of more than 17 per cent, estimation by log grades gave an error of about 12 per cent. The combination of log sizes and log grades showed the lowest average error for all lumber grades, yet when grade recovery was estimated by the use of log grades alone the maximum error (for No. 2 Common lumber) was less than that when the combination was used.

In addition to its accuracy, ease of application of the method must be given consideration when judging the relative merit of a technique for estimating grade yields. Because four lumber grades are recognized in this study each technique will require a four-category entry for this variable unless the log quality index is employed. The quality index calls for only one entry in cases where it is substituted for the four percentage recoveries. When sizes are used for predictive purposes the number of size classes will obviously be governed by the range in log diameters and the width of the individual diameter classes. (The above described test included logs from 7 inches to 25 inches in d.i.b. hence 10 two-inch classes or 19 one-inch classes were required.) The four log grades, like the four lumber grades, necessitate the use of four separate categories.

If log sizes are used alone for predicting grade recoveries, entries will be required for each diameter-lumber grade category. The use of log grades requires only a fourfold table (for each species) with just 16 possible categories. Log sizes combined with log grades make it necessary to consider four times as many categories as there are log size—log grade items.[15] Thus the easiest of the three techniques to apply is the one whereby grade recovery is estimated by the use of log grades alone. In the illustration which follows log grades are used exclusively for predicting lumber grade yields.

LUMBER VALUE MAY BE ESTIMATED FROM GRADE YIELD AND OVERRUN DATA

As an example of the process involved in the estimation of lumber values from the attributes of logs, consider the information in Table 5. Species, log diameter, log grade and the actual yield of lumber by grades are shown for each of 40 logs sawed in two Indiana band sawmills. All are 12-foot logs. An illustrative calculation of lumber yield values is made below that utilizes only the first three columns of Table 5 and the results tabulated and discussed elsewhere in this study. In determining the lumber value of a run of logs, log sizes are necessary to estimate volumes, log grades are necessary to estimate grade recoveries, and it is necessary to separate logs by species in order that differences in price may be considered. The true grade yield data of Table 5 are used to check the estimates of volume and value for these 40 logs.

Since lumber values are calculated on a mill tally basis, the first step in predicting these values is always that of converting log scale into mill tally by applying overrun information. On page 30 the treatment of overrun in board foot units, rather than as percentages of log scales was suggested. Table 6 demonstrates the conversion of Doyle log scale into band mill tally for 12-foot logs using the appropriate rule of thumb. The estimated mill tally for each size of log is used hereinafter without recourse to log scales.

Table 7 includes the estimates of mill tally according to species and grade of log. For instance, the first log in Table 5, a 10-inch, grade No. 3, basswood, is entered in Table 7 simply as 62 board feet in the appropriate column and row. Likewise the estimate of mill tally for a 14-inch, grade No. 1 red oak log may be seen as 108 board feet entered under "red oak" and opposite the No. 1 log grade. The total estimates of sawed volume for each species and log grade are also included in Table 7. The 40 logs showed an estimated yield of 5484 board feet.

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[15] These will total somewhat fewer than four times the number of diameter classes, since all log grades cannot occur in all size classes.

TABLE 5. Actual Grade Recovery from Forty 12-foot Logs Sawed in Two Indiana Band Mills.

Species	d.i.b. inches	Log grade	board feet, mill tally				
			FAS	No. 1C	No. 2C	No. 3C	Total
Basswood	10	3	..	..	52	..	52
Basswood	10	2	..	..	10	62	72
Poplar	10	2	19	14	14	4	51
Poplar	12	3	..	18	44	21	83
Sugar	12	3	..	18	47	4	69
Sugar	12	2	..	46	26	30	102
Red oak	12	2	..	43	11	36	90
Red oak	12	2	28	21	6	30	85
Basswood	12	2	..	..	59	3	62
Poplar	12	2	..	20	16	46	82
Red oak	14	3	8	28	15	24	75
Sugar	14	3	..	42	22	25	89
Poplar	14	2	..	7	87	3	97
Sugar	14	2	30	44	12	12	98
Sugar	14	2	..	71	30	30	131
Sugar	14	2	..	16	..	69	85
Red oak	14	1	5	23	18	24	70
Basswood	14	1	..	34	51	12	97
Poplar	14	1	..	159	3	21	183
Poplar	14	1	..	48	32	36	116
Poplar	14	1	..	25	66	45	136
Sugar	16	2	10	56	20	34	120
Sugar	16	1	29	36	20	18	103
Sugar	16	1	10	90	..	35	135
Red oak	16	1	9	50	34	34	127
Basswood	16	1	..	81	41	29	151
Poplar	16	1	..	106	14	..	120
Poplar	16	P	..	86	16	47	149
Red oak	16	P	50	56	16	16	138
Poplar	18	2	..	46	98	..	144
Red oak	18	1	34	92	3	40	169
Red oak	18	1	126	36	8	24	194
Red oak	18	P	135	50	5	..	190
Beech	20	3	...	67	6	144	217
Beech	20	2	36	117	18	63	234
Poplar	20	1	...	126	35	35	196
Red oak	20	P	124	53	5	28	210
Beech	22	2	19	112	39	120	290
Beech	22	1	25	155	33	96	309
Sugar	22	P	40	165	15	38	258

TABLE 6. Estimation of Band Mill Tally from Doyle Log Scale for 12-foot Logs.

Log d.i.b. (inches)	10	12	14	16	18	20	22
Log scale (bd. ft.)	27	48	75	108	147	192	243
Overrun (bd. ft.)[1]	35	34	33	32	31	30	29
Estimated mill tally (bd. ft.)	62	82	108	140	178	222	272

[1] Equivalent to: 40 — D/2. See page 30.

TABLE 7. Estimation of Mill Tally from Forty 12-foot Logs for Band Mills.

Log grade	Estimated Mill Tally by Species—Board Feet					
	Basswood	Beech	Sugar	Red Oak	Poplar	Total
Prime			272	140 178 222 —— 540	140	952
No. 1	108 140 —— 248	272	140 140 —— 280	108 140 178 178 —— 604	108 108 108 140 222 —— 686	2090
No. 2	62 82 —— 144	222 272 —— 494	82 108 108 108 140 —— 546	82 82 —— 164	62 82 108 178 —— 430	1778
No. 3	62	222	82 108 —— 190	108	82	664
Total	454	988	1288	1416	1338	5484

The estimates of the yields by lumber grades are calculated in Table 8. Based upon the percentages of the four lumber grades recovered from the several log grades, but irrespective of log sizes, the estimated mill tally from Table 7 is broken down into lumber grade yields. Table 7 includes a total yield of 540 board feet from Prime red oak logs. The percentage recoveries from all Prime logs (irrespective of species) are 43, 33, 7 and 17, respectively, for the four lumber grades from FAS to No. 3 Common. Accordingly, the 540 feet of Prime red oak are segregated in Table 8 as 232, 178, 38 and 92 board feet, respectively, from the best to the poorest grades of lumber. Even though the same percentages of grade recovery are applied to all species in a

given log grade, the yields by species are kept separate in order to apply the proper prices in calculating values. The totals at the bottom of Table 8 are simply summations of the estimated yields of the four separate grades of lumber.

Table 9 compares the actual grade yields for the 40 logs itemized in Table 5 with those estimated in Table 8. Many discrepancies in the yields are in evidence. A volume of 64 feet was estimated to be the FAS yield of basswood lumber yet none of the five logs of this kind included in the sample yielded any lumber of this grade. Apparently more serious is the error for

TABLE 8. Estimation of Lumber Grade Recovery from Forty 12-foot Logs.

Log grade	Lbr. grade	Percentage recovery[1]	Estimated mill tally by species and lumber grades—bd. ft.				
			Basswood	Beech	Sugar	Red Oak	Poplar
					272	540	140
	FAS	43			117	232	60
Prime	No. 1C	33			90	178	46
	No. 2C	7			19	38	10
	No. 3C	17			46	92	24
			248	272	280	604	686
	FAS	21	52	57	59	127	144
No. 1	No. 1C	40	100	109	112	241	275
	No. 2C	19	47	52	53	115	130
	No. 3C	20	49	54	56	121	137
			144	494	546	164	430
	FAS	8	11	40	44	13	34
No. 2	No. 1C	36	52	178	197	59	155
	No. 2C	27	39	133	147	44	116
	No. 3C	29	42	143	158	48	125
			62	222	190	108	82
	FAS	1	1	2	2	1	1
No. 3	No. 1C	25	15	55	48	27	20
	No. 2C	35	22	78	66	38	29
	No. 3C	39	24	87	74	42	32
			454	988	1288	1416	1338
	FAS		64	99	222	373	239
Total	No. 1C		167	342	447	505	496
	No. 2C		108	263	285	235	285
	No. 3C		115	284	334	303	318

[1] Taken from the last column of Table D-1 in the Appendix.

the same grade of poplar lumber which shows an actual recovery of 19 board feet in contrast to an estimate of 239 feet. A discussion of these errors is justified.

The majority of the errors in estimating lumber grade yields, as seen in Table 9, arises from the extreme variability of hardwood logs. This type of error diminishes in magnitude as the number of logs is increased; for single logs the predicted grade yield may be exceedingly inaccurate. These errors average out, however, on a large number of logs.

The total mill scale for the 40 logs (5,379 board feet) was overestimated by a mere 105 board feet which constitutes an error of less than two percent. Whereas the lumber yields for individual species and individual grades of lumber were estimated with much less precision, it is obvious that the compensative nature of log variability is effective in the total volume.

Another type of error is also in evidence in Table 9. The very great overestimate of FAS poplar lumber, referred to previously, is due in a large measure to the fact that the Selects grade has been included with the No. 1 common grade in this study. (See footnote on page 15.) If the yields for the two best lumber grades in Table 9 are lumped, it is seen that the over-

TABLE 9. Comparison of Actual and Estimated Grade Recovery from Forty 12-foot Logs.

Species	Total Mill Tally in Board Feet									
	FAS		No. 1C		No. 2C		No. 3C		Total	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
Basswood	...	64	115	167	213	108	106	115	434	454
Beech	80	99	451	342	96	263	423	284	1050	988
Sugar	119	222	584	447	192	285	295	334	1190	1288
Red Oak	519	373	452	505	121	235	256	303	1348	1416
Poplar	19	239	655	496	425	285	258	318	1357	1338
Total	737	997	2257	1957	1047	1176	1538	1354	5379	5484

TABLE 10. Comparison of Actual and Estimated Lumber Value[1] from Forty 12-foot Logs.

Species	Total Lumber Value in Dollars									
	FAS		No. 1C		No. 2C		No. 3C		Total	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
Basswood	....	5.37	6.90	10.02	9.16	4.65	2.44	2.64	18.50	22.68
Beech ...	6.75	8.36	25.92	19.69	3.94	10.80	12.06	8.10	48.67	46.95
Sugar ...	12.14	22.62	41.45	31.75	8.45	12.55	7.38	8.35	69.42	75.27
Red Oak..	43.10	30.95	27.55	30.80	5.32	10.34	6.41	7.59	82.38	79.68
Poplar ..	1.69	21.28	40.60	30.75	19.33	12.97	5.94	7.32	67.56	72.32
Total ..	63.68	88.58	142.42	123.01	46.20	51.31	34.23	34.00	286.53	296.90

[1] Prices are taken from Table 1, page 14, for illustrative purposes.

estimate of FAS poplar lumber is nearly counterbalanced by an underestimate of No. 1 Common lumber. The estimated yield for both grades is 735 feet as compared with the actual yield of 674 board feet. Although errors due to inconsistencies in lumber grading practices among species are systematic, they, too, tend to be compensative in the aggregate.

The conversion of volumes by species and grades of lumber, as shown in Table 9, to values, as shown in Table 10, is only a matter of multiplying by the appropriate prices. The conversion from Table 9 to Table 10 was carried

out by means of the price structure shown in Table 1. (It should be remembered that these prices are used herein solely for illustrative purposes.) Eighty feet of FAS beech at $84.50 per MBM have a value of $6.75. Similarly, 451 feet of No. 1 Common lumber of the same kind are worth $25.92, since this grade is priced at $57.50 per MBM. The volumetric errors which appear in Table 9 obviously are carried along in the values of Table 10. The error of estimating the value of lumber cut from the 40 logs amounted to $10.37 which was approximately three and one-half percent of the actual value of all the logs.

THE QUALITY INDEX SIMPLIFIES THE PREDICTION OF LUMBER VALUES

All lumber grade recovery data derived in this study are easily expressed in terms of the log quality index. (See page 13.) The index provides a clue to the quality yield of any log when the yields of the several lumber grades are weighted according to their relative monetary values. Because it denotes average quality in a single quantitative expression, the log quality index is much simpler to use in estimating lumber values than are the individual percentage recoveries of the four lumber grades.

The estimated mill tally figures in Table 11 are copied from Table 7. Table 11 makes unnecessary the use of percentage grade recoveries (see Table 8) in calculating lumber values since it utilizes the comparable quality indexes. Instead of four entries (one for each lumber grade) for each log grade, a single quality index figure is shown for each log grade.

The average quality index for grade No. 1 logs is 64.5, which means that, as a rule, lumber from No. 1 logs will be worth 64.5 percent as much per MBM as is FAS lumber of that species. Sugar maple is priced at $102.00 per thousand feet in Table 1, hence No. 1 sugar maple logs will yield lumber worth:

.645 × $102.00 = $65.79 per MBM,

on the average. The estimated volume of 280 board feet of sugar maple lumber cut from a No. 1 log has a value, therefore, of:

.280 × $65.79 = $18.42, approximately.

Each of the estimated volumes in Table 11 was converted into value by multiplying the appropriate quality index by the selling price of the FAS grade for the correct species, and this product by the volume in thousands of board feet.

The total lumber value of each species at the bottom of Table 11 may be compared with the similar entries in the last double column of Table 10. It is readily apparent that estimation of value by use of the quality index gives results that are nearly as accurate[16] as is estimation by means of percentage recoveries. The use of the quality index, moreover, requires only about one-fifth as many computations as the technique of using percentages. The error in the total estimated value in Table 11 is $13.28, or approximately four and one-half percent of the actual lumber value. Hence the use of the quality index for predicting lumber values is thoroughly justified.

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[16] The quality index technique will tend to overestimate value consistently by a small amount. This is due to the fact that grade value differentials that are slightly too high are used in calculating the quality index. See page 13.

TABLE 11. Estimated Lumber Value from Forty 12-foot Logs Through Use of the Quality Index.

Mill tally and value by species

Log grade	Quality Index[1]		Basswood	Beech	Sugar	Red Oak	Poplar	Total
			FAS Price per MBM[2]					
			$84.00	$84.50	$102.00	$83.00	$89.00	$
Prime	74.7	bd. ft.			272	540	140	
		$			20.73	33.48	9.31	63.52
No. 1	64.5	bd. ft.	248	272	280	604	686	
		$	13.46	14.86	18.42	32.35	39.41	118.50
No. 2	55.4	bd. ft.	144	494	546	164	430	
		$	6.70	23.11	30.80	7.54	21.20	89.35
No. 3	47.7	bd. ft.	62	222	190	108	82	
		$	2.48	8.95	9.25	4.28	3.48	28.44
Total		$	22.64	46.92	79.20	77.65	73.40	299.81

[1] Taken from last line of Table D-2 in the Appendix.

[2] Prices are taken from Table 1, page 14, for illustrative purposes.

COSTS, AS WELL AS LUMBER VALUES, DETERMINE THE WORTH OF STUMPAGE

Some owners of standing timber not entirely familiar with all phases of lumbering assume that log values approach lumber values. They forget the manufacturing costs involved. Costs of felling, log-making, skidding, loading, and transportation, as well as the actual cost of sawmilling must all be borne by the sale price of lumber, in addition to many indirect classes of cost.

The direct costs of logging and milling vary appreciably with tree or log size; the manufacture of a unit volume of lumber from large trees or logs is much less costly than from small trees or logs. In addition to the cost differentials due to tree or log size, no two operators will have identical costs for the same process nor will the same operator experience the same cost for two separate operations. Hence it is impossible to ascribe a fixed allowance for converting lumber values into log or tree values.

Another reason why log values do not equal lumber values is that in converting logs into lumber an operator assumes certain risks, and the assump-

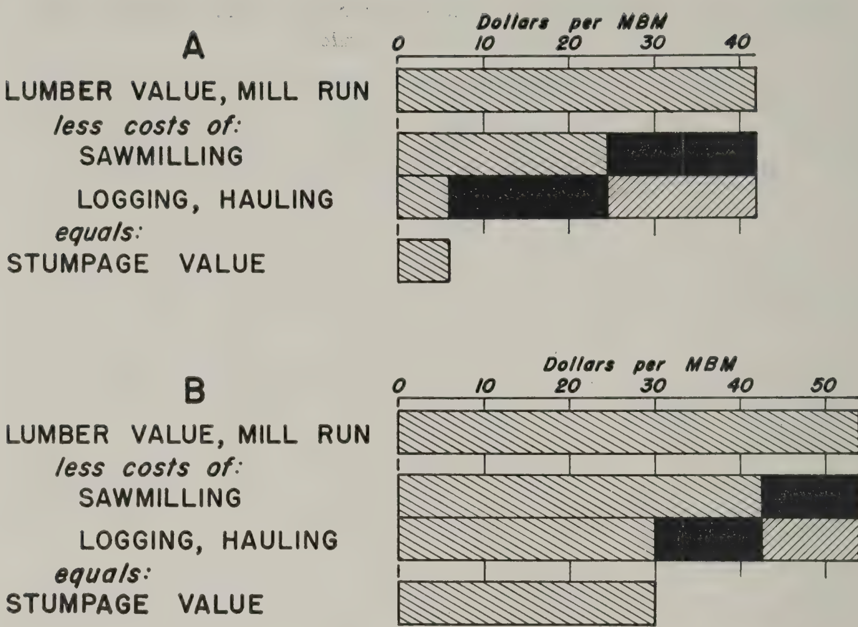

Figure 12. Determination of stumpage values from: (A) low-valued lumber with high production costs, and (B) high-valued lumber with low production costs.

tion of such risks warrants a margin of safety. As stated earlier, No. 3 Common lumber practically always costs more to manufacture than it is worth and sawmill operators typically gamble on how much they stand to lose on this low grade material. Then too, air seasoning of lumber requires from four months to two years, which means that lumber manufacturers must normally carry a rather high yard inventory. (Probably less than 10 percent of the lumber cut in Indiana is kiln-dried directly from the green condition.) In buying timber or logs, therefore, an operator must consider the effects of a falling market price in conjunction with his stock on hand; he must allow for the risk in buying timber today and selling the lumber perhaps a year from today.

Appraisal of the value of standing timber, if it is to be done analytically, must begin with the value of the manufactured product at the mill. By successively subtracting the costs of manufacture from the selling price of lumber, one may calculate the value of the raw material itself, or the value of the product at any stage of refinement. The accompanying graph, Figure 12 represents the process of converting selling price into stumpage value. Since logging and milling costs vary widely per MBM with tree or log size, no attempt is made to show costs of specific operations. Figure 12-A indicates that with a low lumber value per MBM and a relatively high cost of manufacture, characteristic of small timber, stumpage value is very low. Similarly if lumber values are higher because timber is larger or of better quality, and logging and milling costs are relatively low, a much higher price may be paid for standing timber. (Figure 12-B.) It must be emphasized that costs and values in Figure 12 cannot be accepted for specific logging and milling opera-

tions; the graph merely suggests the method of converting lumber values into tree or log values. Stumpage owners should recognize that these costs exist and not tend to overvalue their standing trees.

STUMPAGE VALUE MAY BE APPRAISED BY USING A SINGLE FORM

A tally-computation sheet such as that shown in Figure 13 provides a convenient form for appraising farmwoods sawtimber.[17] The sheet carries the estimated band and circular mill tallies for 12-foot logs of various diameters. There is a row in the heading of the tabulation for entering the selling prices of the best (FAS) grade of lumber of the various kinds of timber. In use, the estimated mill tally volumes are entered, log by log, and totalled for each species and grade of log. (See Table 7.) These volumes are then converted to values by multiplying by the corresponding quality indexes and FAS prices. (See Table 11.)

If the volume estimate will not total more than 10 MBM made up of several species, all logs may be tallied on the same sheet that is used for computing value, but the sheet illustrated is not adapted to heavier tallies. For more than 10 MBM, the estimates of mill tally by species and log grade may be entered on several sheets, which are later combined, or a conventional tally of individual 12-foot logs by d.i.b., species and grade may be taken in the field and converted to volume later on. In any event the conversion of volume to value is easily accomplished by the use of the form in Figure 13.

Selling prices of FAS lumber and estimates of total production costs should be obtained from personal interviews with operators of sawmills who could be potential purchasers of the timber to be appraised. Total production costs must include a margin of about 20 percent of the average investment for profit and risk, as well as the more obvious expenses incurred in logging and milling. Total estimated value divided by the total estimated volume (lower right corner of Figure 13), equals the average selling price per MBM. After costs are deducted, there remains the estimate of stumpage value on a unit volume basis. The indicated stumpage value is in terms of mill tally, but may be converted to log scale by multiplying by one plus the overrun.

VI. THE COMMON AIMS OF THE WOODS AND MILL OWNERS

FARMERS SHOULD BE INTERESTED IN SAWLOG VOLUMES

The timberland owner should realize that size alone is an important attribute of sawlogs, for size not only controls the volume of a log, it is directly associated with value as well. This study has shown that, on a percentage basis, small logs scale considerably less than their actual content, that is, the overrun is relatively high from small logs. Figure 14 compares the overrun from the Doyle rule for 12-, 18-, and 24-inch logs, 12 feet in length. Figure 14-A shows the high percentage overrun from 12-inch logs as contrasted with 18- and 24-inch logs.

If a farmer sells 1,000 board feet of 12-inch logs and disregards the overrun which they will yield, he actually gives away 650 additional board

[17] This tally sheet has been filled in with the mill tally estimates of Table 11 except that values have been calculated only to the nearest ten cents from the quality indexes printed on the sheet. Total cost is estimated at $35.00.

TALLY - COMPUTATION[1/] SHEET FOR APPRAISAL OF FARMWOODS TIMBER

(12-FOOT LOG STANDARD)

Log dib (in.)	Estimated Mill Tally: Band	Circle
8	48	40
10	62	52
12	82	70
14	108	94
16	140	124
18	178	160
20	222	202
22	272	250
24	328	304
26	390	364
28	458	430
30	532	502
32	612	580
34	698	664
36	790	754

Log Grades
-0-

P – *90% clear. 16" & up.*
1 – *75% clear. 14" & up.*
2 – *50% clear in 2 cuttings > 3' long. 10" & up.*
3 – *Will not make No. 2.*

Log Grade	Qual. Ind.	Species								
		Basswood	Beech	Sugar	Red oak	Poplar				
		FAS Price per M								
		84.00	84.50	102.00	83.00	89.00				
P				272	540	140				
	0.75			20.80	33.60	9.30				
1		248	272	280	604	686				
	0.65	13.60	15.00	18.60	32.60	39.70				
2		144	494	546	164	430				
	0.55	6.70	22.90	30.60	7.50	21.00				
3		62	222	190	108	82				
	0.48	2.50	9.00	9.30	4.30	3.50				
All	Bd.ft	454	988	1288	1416	1338				5,484
	$	22.80	46.90	79.30	78.00	73.50				300.50

[1/] Multiply: Quality index
X FAS price per M
X Mill tally in MBM

Selling price per M .... $ 54.80
Estimated cost per M 35.00
STUMPAGE VALUE .... $ 19.80

Figure 13. Tally-computation sheet for appraisal of farmwoods timber.

feet in the transaction unless an adjustment in price is made, since the overrun amounts to 65 percent. If the 1,000 feet were made up of 24-inch logs, however, the overrun would amount to only 80 board feet. These facts may be substantiated by considering Figure 14-B. At a scale volume of less than 50 feet per log, if the logs are 12 inches in d.i.b. it requires more than 20 logs to total 1,000 board feet. The graph shows that the difference between the log and mill scales for this size is approximately 30 board feet per log. Hence the overrun from these logs would total to more than 600 board feet.

The scale volumes by the Doyle rule for the three sizes of log shown in Figure 14-B increase about in the ratio 1:3:6. In other words, the scale volume increases six-fold while the log diameter increases from 12 to 24 inches. In a sense, then, any woodland owner who felt justified in growing a 12-inch log should have six times the incentive to let it double in diameter Arbitrarily allowing a growth rate of two inches in diameter every 10 years, the 12-inch log will yield 3.8 percent compound interest on its original volume if allowed to grow into an 18-inch log; it will yield 3.1 percent compound interest if left until it is 24 inches in diameter.[18] It is folly to convert a

[18] These interest rates merely represent increments in board foot volume. See page 44 for the effects of growth upon value.

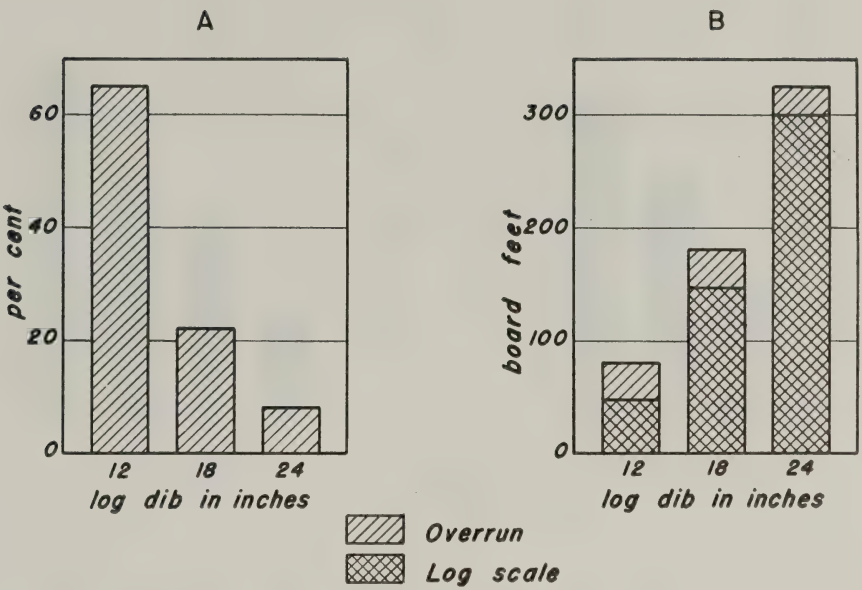

Figure 14. Overrun from the Doyle rule for 12-foot logs in: (A) percent and (B) board feet.

tree into lumber just as soon as it contains one small log, because the tree will increase in volume alone rapidly enough to earn a creditable rate of interest. The farmwoods owner must control the minimum size of the trees cut and acknowledge the fact that any small tree left uncut contributes to the growth rate of the stand. Accordingly a good woods manager will never allow a second mill operator to "slash" the woods after another logger has practiced good forestry and has cut only the larger timber.

Farmers can maintain a high rate of growth in their woods by eliminating certain practices. Overcutting, pasturing, and burning are three important practices which reduce the growth rate of a stand. Removal of all merchantable timber by logging, undesirable as the practice is from economic aspects, exposes the site to both sun and wind and reduces its quality. Pasturing removes the reproduction in a woods and seriously compacts the soil. If continued over a period of years pasturing will reduce the density of a farmwoods to such an extent that tree growth is negligible. Similarly, woods fires reduce stand density, and their damage to soil and lumber quality may also be appreciable.

QUALITY IS ALSO IMPORTANT TO THE FARMWOODS OWNER

The farmer-producer of sawlogs must recognize that two logs of exactly the same size and species may contain radically different yields in quality of lumber. He should appreciate that by cutting only those trees which have attained considerable size, he can demand a higher price per thousand board feet than if he cuts trees as small as 12 or 14 inches in diameter. Yet rough, low-grade logs sawed from open-grown trees, even though they are quite large in diameter, will yield only a small percentage of high-grade lumber. Timber buyers cannot pay top prices for such logs.

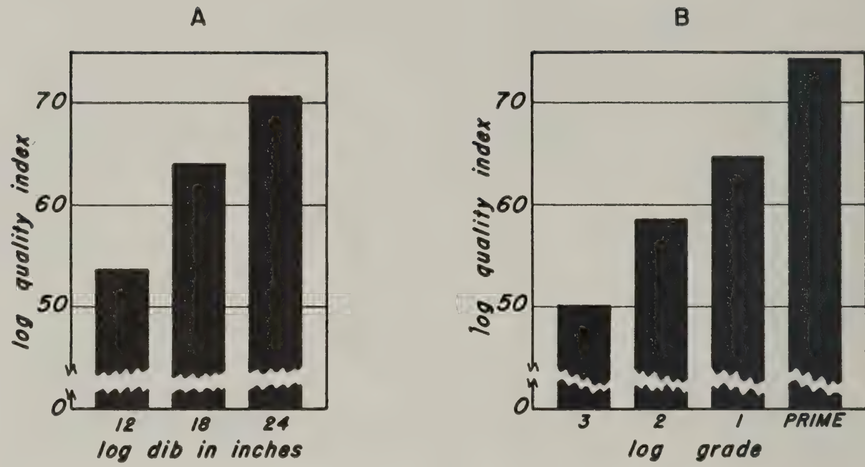

Figure 15. Average quality yields for (A) three sizes of log and (B) four grades of log.

The effects of log size upon the average quality yield of lumber are shown in Figure 15-A. At current lumber prices, ***the lumber cut from*** a 12-inch log is worth about $2.25, from an 18-inch log about $8.25, and that from a 24-inch log about $18.50, considering volume as well as grade yields. ***On the stump these logs would all be worth less,*** but the value differentials between sizes would be much greater. (See page 22.) Even though the high cost of manufacturing lumber from small logs is totally neglected and a comparison is made of the value of the lumber yields from logs of these three sizes, the differences are significantly great. Again, if a growth rate of two inches in 10 years may be assumed, the 12-inch log will be worth at least four times as much of it is left to grow to an 18-inch size; its value will increase at least eight times if allowed to double in diameter. Because large trees and logs are worth so much more than small ones, a farmer should aim to produce such high quality logs and trees.

Figure 15-B has been reproduced from the tabulation on page 15. It illustrates that high-grade logs, as evidenced by size and exterior indications of quality, yield better lumber than poorer logs. On a unit volume basis, lumber from the average Prime log is worth (at current lumber prices), $9 more than lumber from the average No. 1 log, $14 more than that from the average No. 2 log, and $21 more than lumber from the average grade No. 3 log. It is to his obvious advantage, for a farmer to grow as many high-grade logs as possible.

Log or tree quality is influenced by cutting, pasturing, and fire in the same manner as volume, because quality also relates to stand density. But the quality of a tree can be cultivated directly, as well as through such indirect measures as eliminating overcutting, excluding livestock and protecting from fire. By artificial pruning of his ultimate crop trees when they are yet small, a farmer may be able to improve their final quality. Artificial pruning, however, is expensive and silvicultural skill is necessary for the proper selection of crop trees. Maintenance of good woods conditions and a fairly close spacing of trees, moreover, will be conducive to natural pruning and relatively high grades of tree will result.

HOW A FARMER CAN PRODUCE HIGH-VALUE SAWLOGS

The following items are worthy of the consideration of the woods owner who would grow quality sawtimber:

1. ***Know what constitutes a high-grade sawlog.*** The log grades described previously serve to identify valuable trees and logs. Ability to measure and grade them is helpful in recognizing how to grow top quality sawlogs.

2. ***Choose the ultimate crop trees and let them grow.*** Volume and value increases are greatest after trees have attained the minimum merchantable size (12 to 14 inches in diameter). Each year of growth beyond this size is worth 5 or 10 times as much as each year required to attain the size. Poorly-formed trees and undesirable species should be "weeded out" of the stand, especially if they are interfering with crop trees.

3. ***Harvest mature trees only.*** Quality is highest and manufacturing costs are lowest for large trees and logs. Select trees for cutting which are large enough to yield little overrun and yet contain a maximum of high-grade lumber. Do not allow trees to become over-mature—they deteriorate and lose value, but avoid dealing with an operator who will ruin a woods by overcutting.

4. ***Maintain good growing conditions.*** Prevent woods fires and exclude livestock in order to secure the maximum growth rate. Burning and pasturing cause soil deterioration, reductions in stand density and spoilage of standing timber.

5. ***Do business with a reputable timber buyer.*** The processor of sawlogs is as interested in buying only high-value logs as the farmer is in selling them. Buyers of trees and logs who are representatives of permanent industries realize that:

   a. smaller immature trees left to grow will provide another cut in 5, 10, or 15 years, and

   b. their reputations depend upon what they pay for timber.

   A reliable sawmill operator will help a farmer grow good timber.

EVERY MILL OPERATOR IS CONCERNED WITH OVERRUN

Many lumber manufacturers like to cut small logs on the assumption such logs yield a very high overrun. On the basis of percentages, this assumption is correct, for 12-inch logs in this study gave a percentage overrun eight times as great as 24-inch logs. (See Figure 14-A.) But actually the overrun from 12-inch logs was not higher than that from 24-inch logs by more than a few board feet. Large logs yielded almost as much excess volume as small logs. (See Figure 14-B.)

Considering only the direct costs of sawmilling,[19] the expense involved in sawing 1,000 board feet of overrun from (about 32) 12-inch logs is very much higher than the cost of processing such excess volume from larger logs. Figure 16 compares the costs of sawing a unit volume from three sizes of log in Indiana band mills. Based upon the cost per MBM of sawing 24-inch

[19] Disregarding logging and transportation costs, which would serve to accentuate the differences here shown.

logs, 18-inch logs cost five percent more and 12-inch logs cost 27 percent more. It should be clear, therefore, that small logs do not yield appreciably higher board foot overruns than large logs but that the excess volume cut from small logs is "high cost" overrun.

QUALITY IN THE LOG MEANS QUALITY AT THE MILL

Mill men need not be referred to Figure 15-A; they know full well the increase in log quality with size. Attention is called, however, to Figure 15-B, which shows the relation existing between quality yields and log grades. The rise in average lumber quality with improving log grades is apparent. This rise is generally recognized by mill operators and so is not a new conception, but Figure 15-B prompts the mention of two other matters:

a. the log quality index is a new means of expressing average lumber grade recoveries, and

b. the lumber quality that sawlogs will yield may be estimated by the use of log grades.

Studies of lumber grade recovery which have been made by Indiana hardwood operators have been "aggregate studies", that is, they have included all logs in a day's run or in a week's output. Little attention has been paid to the influence of either log size or individual log quality upon the grades of lumber produced. It is almost certain to be true that in the immediate future, more consideration will have to be given to the unit log.

Keener competition among buyers of sawlogs and more spirited bidding for available timber will soon characterize the hardwood lumbering industry of Indiana. Such conditions will require strict log quality control. Whether or not the specific log grades as advocated in this study are suitable for adoption by industry, grading schemes will have to be devised and preferably a standard set of grading rules agreed upon. Two sets of hardwood log grading rules issued by the O.P.A. are included in Appendix B. The suggested log quality index should prove to be beneficial for translating lumber yields into a simple numerical symbol.

LOG SIZE DESERVES MORE ATTENTION FROM THE LUMBER MANUFACTURER

Logs from 16 to 24 inches in diameter (the equivalent of trees more than 18 inches in diameter) are accepted as being of the optimum size by most mill men. Such logs are cheaper to process than smaller ones, yet they are not so large as to tax the capacity of logging and milling equipment. Why does a sawmill operator bother with smaller logs? There are at least two reasons:

a. He feels that he needs the additional volume from small logs to carry his "overhead costs", or

b. He buys his timber on a "lump sum" basis and therefore does not feel justified in leaving any board foot volume in the woods.

Neither of these reasons is defensible.

The "additional volume from small logs" can more profitably come from additional large logs. The scarcity of large timber is perhaps more apparent than real. There is large timber available at a fair purchase price just as

there is much mature timber that is spoiling because the owners have a misconception as to its value for lumber. (See pages 4, 12 and 41.) Admittedly no operator can pay as much for timber averaging 16 inches in diameter as if the timber were 20 inches in average size. But by refusing to buy or handle small timber, an operator can keep his costs down and values up and thereby afford to pay high prices for the "additional volume" that he needs.

Of course, there is another advantage to the sawmill owner in avoiding small sized trees and logs, and in paying a higher price for the better timber he does buy. Trees less than 18 inches in diameter, if allowed to grow, will produce logs of the optimum size, described above, in 10 or 20 years, thus they will provide a second cut for the mill owner. A fair price per thousand in the original sale will lead to second and suceeding transactions between the producer and the processor. However, the farmer must be responsible for maintaining a good residual stand. He must not sell the mature timber to a reputable mill operator and then allow a fly-by-night operator to cut all remaining trees that contain any board foot volume. Judicious use of existing timber resources will insure a permanent sawmilling industry, whereas unsound cutting practices now will certainly eliminate the sources of supply of many mills in the near future.

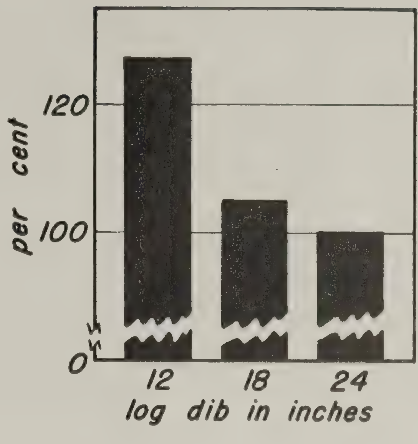

Figure 16. Relative cost per MBM of sawmilling three sizes of log.

WHY THE MILL OWNER SHOULD PROCESS ONLY HIGH-VALUE SAWLOGS

In summary form there are four good reasons, recognized by some lumbermen, why they should deal in quality logs only:

1. ***Overrun from small logs is costly.*** The actual board foot overrun from small logs is not much higher than that from large logs but it is produced at a very much higher cost per thousand feet. Most of this expensive overrun from small logs is No. 2 and No. 3 Common lumber, of which there is no scarcity.

2. ***The margin is wide on large logs.*** In general, the larger the log the greater the operating margin. This is because costs are low and the grade yields of lumber are high. High margins on large logs are actually concealing the losses sustained in processing small logs in many Indiana mills today. These mills could make more money by cutting only those logs that will yield a profit; any volume deficit arising because small logs are not cut, can be met by additional large logs. These additional logs will cost money but they will yield a profit, not a loss.

3. ***High prices gain the confidence of woods owners.*** By buying on log grade and log scale the lumberman can pay higher prices per thousand

board feet because he is not obligated to buy poor quality or small logs. Low grade logs can best be custom sawed for use on the farm, while trees containing only small logs should be allowed to grow to a profitable size. If the quality timber in a woods is worth $100, it is better for the buyer's reputation if he pays $100 for the quality timber only, than if he takes the unprofitable timber also. Thirty dollars a thousand for 3,300 board feet is certainly a more profitable sale than 5 MBM at $20 and it may be a much more profitable buy.

4. ***Partial cutting means shorter cutting cycles.*** One thousand feet in trees 12 to 18 inches in diameter, if left to grow for 10 years should amount to 1,600 feet. The value should increase more than $30, because quality as well as the volume will be higher. Any operator who aims to stay in business must plan for his future sawlog supply. Partial cutting coupled with the confidence of the woods owners will go a long way toward insuring a permanent supply of raw material for the lumber industry of Indiana.

APPENDIX A

LIST OF COOPERATING SAWMILLS

Name	*Location*	*Type of Mill*
Adams County Lumber Co.	Decatur	Circular
C. H. Barnaby	Greencastle	Band
Thos. Crumley	LaFontaine	Band
Ditzler Lumber Co.	Huntington	Circular
Herman Frick	Brimfield	Circular
Galbraith and Sons	Sunman	Band
T. P. Graham Lumber Co.	Franklin	Band
McDowell Lumber Co.	Bluffton	Circular
D. A. Pike Lumber Co.	Akron	Circular
A. J. Sanders and Son	Whitaker	Band
Sanders Lumber Co.	South Bend	Band
Frank Stevens Lumber Co.	Wabash	Circular
H. A. Woods Lumber Co.	Grabill	Circular

APPENDIX B

LUMBER GRADES, LOG RULES, AND LOG GRADES

Brief Description of Hardwood Lumber Grades

Doyle, Scribner D. C., and International (¼-inch) Rules

Purdue Log Grades

O.P.A. Log Grades

O.P.A. Log Grades for Northern Ohio

A BRIEF DESCRIPTION OF HARDWOOD LUMBER GRADES

The following excerpts from, "How Lumber is Graded" (1) will serve as a brief summary of hardwood lumber grades:

. "The highest grade of hardwood lumber is termed 'Firsts' and the next grade 'Seconds'. Firsts and Seconds, or, as they are generally written, FAS are practically always combined in one grade. The third grade is termed 'Selects' followed by No. 1 Common, No. 2 Common, Sound Wormy, No. 3-A Common, and No. 3-B Common".

"The highest grade, Firsts, calls for pieces which will allow 91⅔ percent of their surface measure to be cut into clear-face material; i. e., not more than 8⅓ percent of each piece can be wasted in making the required cuttings. In the grade of Seconds, 83⅓ percent of the surface measure of the pieces must yield clear-face cuttings.[1] Both Firsts and Seconds requires pieces not

---

[1] Boards 6 feet to 15 feet surface measure will admit of one additional cutting to yield 91⅔ percent clear face.

TABLE B-1. *Doyle Log Rule.*

Top diameter (inches)	Length in Feet				
	8	10	12	14	16
	Volume in Board Feet				
8	8	10	12	14	16
9	13	16	19	22	25
10	18	23	27	31	36
11	25	31	37	43	49
12	32	40	48	56	64
13	41	51	61	71	81
14	50	63	75	87	100
15	61	76	91	106	121
16	72	90	108	126	144
17	85	106	127	148	169
18	98	123	147	172	196
19	113	141	169	197	225
20	128	160	192	224	256
21	145	181	217	253	289
22	162	203	243	284	324
23	181	226	271	316	361
24	200	250	300	350	400
25	221	276	331	386	441
26	242	303	363	424	484
27	265	331	397	463	529
28	288	360	432	504	576
29	313	391	469	547	625
30	338	423	507	592	676
31	365	456	547	638	729
32	392	490	588	686	784
33	421	526	631	736	841
34	450	563	675	788	900
35	481	601	721	841	961
36	512	640	768	896	1024
37	545	681	817	953	1089
38	578	723	867	1012	1156
39	613	766	919	1072	1225
40	648	810	972	1134	1296

TABLE B-2. Scribner Decimal C Log Rule.

Top diameter (inches)	Length in Feet				
	8	10	12	14	16
	Volume: Board Feet in Tens				
8	1	2	2	2	3
9	2	3	3	3	4
10	3	3	3	4	6
11	3	4	4	5	7
12	4	5	6	7	8
13	5	6	7	8	10
14	6	7	9	10	11
15	7	9	11	12	14
16	8	10	12	14	16
17	9	12	14	16	18
18	11	13	16	19	21
19	12	15	18	21	24
20	14	17	21	24	28
21	15	19	23	27	30
22	17	21	25	29	33
23	19	23	28	33	38
24	21	25	30	35	40
25	23	29	34	40	46
26	25	31	37	44	50
27	27	34	41	48	55
28	29	36	44	51	58
29	31	38	46	53	61
30	33	41	49	57	66
31	36	44	53	62	71
32	37	46	55	64	74
33	39	49	59	69	78
34	40	50	60	70	80
35	44	55	66	77	88
36	46	58	69	81	92
37	51	64	77	90	103
38	54	67	80	93	107
39	56	70	84	98	112
40	60	75	90	105	120

less than 6 inches wide and 8 feet long. In the grade Selects the minimum width is 4 inches and the minimum length, 6 feet. Both Firsts and Seconds and the face side of Selects must in addition to cutting requirements also meet specified requirements as to the limitation of certain defects. The cutting requirements of Selects are 91⅔ percent clear face in pieces with 2 and 3 surface feet. In larger pieces, the cutting requirements are the same as for Seconds on the face side. The reverse side of the cuttings in Selects must be sound or the reverse side of the piece not below No. 1 Common. The next two grades, No. 1 Common and No. 2 Common, call for material not less than 3 inches wide and 4 feet long and require[2] 66⅔ percent and 50 percent clear-face cuttings, respectively. The minimum size of cuttings in these two grades is reduced from 4 inches by 5 feet or 3 inches by 7 feet in Firsts, Seconds, and Selects to 4 inches by 2 feet or 3 inches by 3 feet.

[2] Exceptions in No. 1 Common are pieces with 1 foot surface measure and 2 feet surface measure, which require 100 percent clear face and 75 percent clear face, respectively, and in No. 2 Common pieces with 1 foot surface measure, which require 66 percent clear face.

TABLE B-3. International Log Rule (¼-in. Saw Kerf)

Top diameter (inches)	Length in Feet 8	10	12	14	16
	Volume in Board Feet				(nearest 5)
8	15	20	25	35	40
9	20	30	35	45	50
10	30	35	45	55	65
11	35	45	55	70	80
12	45	55	70	85	95
13	55	70	85	100	115
14	65	80	100	115	135
15	75	95	115	135	160
16	85	110	130	155	180
17	95	125	150	180	205
18	110	140	170	200	230
19	125	155	190	225	260
20	135	175	210	250	290
21	155	195	235	280	320
22	170	215	260	305	355
23	185	235	285	335	390
24	205	255	310	370	425
25	220	280	340	400	460
26	240	305	370	435	500
27	260	330	400	470	540
28	280	355	430	510	585
29	305	385	465	545	630
30	325	410	495	585	675
31	350	440	530	625	720
32	375	470	570	670	770
33	400	500	605	715	820
34	425	535	645	760	875
35	450	565	685	805	925
36	475	600	725	855	980
37	505	635	770	905	1040
38	535	670	810	955	1095
39	565	710	855	1005	1155
40	595	750	900	1060	1220

"In the grade of Sound Wormy the requirements are the same as in No. 1 Common except that worm holes and similar defects are allowed in the cuttings. The grade of 3-A Common admits pieces that will furnish 33⅓ percent clear face in cuttings not less than 3 inches wide and 2 feet long. This grade will also admit pieces which grade not below No. 2 Common on the good face and have the reverse face of the cutting sound. The lowest grade, No. 3-B Common, allows pieces that will cut 25 percent in sound material not less than 1½ inches wide and having at least 36 square inches surface measure."

PURDUE HARDWOOD LOG GRADES

Prime practically (90 percent) surface clear on three visible faces.[1] Must be 16 inches or larger in d.i.b.[2]

No. 1 at least three-fourths (75 percent) of length on three visible faces must be surface clear in one cutting.[3] Must be at least 14 inches in d.i.b.

[1] A face is any one-quarter of the surface of the log.
[2] Diameter inside bark at the small end of the log.
[3] A cutting is the length between surface indications of defect, whether sound or unsound.

No. 2 at least one-half (50 percent) of length on three visible faces must be surface clear in two cuttings, neither of which is less than three feet long. Must be at least 10 inches in d.i.b.

No. 3 will not meet No. 2 specifications.

O.P.A. HARDWOOD LOG GRADING RULES

(from Amendment 2 to MPR 533-1, December 20, 1944)

Veneer grade. This grade shall include all logs 18 inches and up in diameter, 10 feet or more in length, and must be straight, clean, and clear of all visible defects.

No. 1 grade. This grade shall include all logs 12 inches and up in diameter that do not have more than two standard 5-inch knots or comparable defect for each 16 feet of length. A center rot or dote in the butt end of the log will be permitted up to 25 percent of the log diameter for logs up to 24 inches in diameter and up to 6 inches for logs in excess of 24 inches in diameter without degrading the log; however, full deduction in scale for the defect must be made when scaling the logs.

No. 2 grade. This grade shall consist of all logs 8 inches and up in diameter that are better than culls and which do not grade as a No. 1 or veneer log.

Woods run grade shall consist of logs 8 inches and up in diameter as produced from the forest that are better than culls and from which no selection of high-quality (No. 1 or Veneer Grade) logs has been made. If any high-quality logs have been removed from the run of logs, the remaining logs must be sold at prices no higher than the No. 2 grade price if ungraded, or at the applicable grade price if graded. When any low-quality logs have been removed from the run of logs, the remaining logs may still be sold at the woods run price.

A cull log shall be one where the net board foot scale after deductions have been made for defect is less than 50 percent of the gross scale.

O.P.A. HARDWOOD LOG GRADING RULES FOR TWENTY-TWO NORTHERN OHIO COUNTIES

(Proposal pursuant to Section 9 (c) of MPR 348, January 27, 1944.)

Clear grade: This grade shall include all logs 24" and up in diameter that are clear of all visible defects.

Select grade: This grade shall include

(a) those logs 16" to 23" in diameter that are clear of all visible defects, and

(b) those logs 24" and over in diameter that have 3 clear faces or 75 percent of the length clear in one continuous section.

APPENDIX C

EXTENT OF BASIC DATA

Distribution of logs and volumes
- by species
- by log grades
- by type of mill

Distribution of logs by diameters and grades
Distribution of logs by lengths and species

TABLE C-1. Distribution of Logs and Volumes.

	Logs		Mill scale volume	
	No.	Per cent	Bd. ft.	Per cent
By Species				
Ash, white	17	1.97	1,418	1.14
Basswood	32	3.72	2,703	2.18
Beech	149	17.31	27,794	23.39
Elm, white	130	15.09	14,477	11.67
Hickory	33	3.83	4,872	3.93
Maple, hard	156	18.12	19,378	15.62
Maple, soft	14	1.63	1,545	1.25
Oak, red	167	19.39	29,183	23.52
Oak, white	29	3.37	6,978	5.62
Poplar, yellow	118	13.70	14,158	11.40
Others	16	1.87	1,690	1.28
Total	861	100.00	124,196	100.00
By Log Grades				
Prime	137	15.9	33,575	27.0
No. 1	198	23.0	30,314	24.4
No. 2	297	34.5	35,451	28.6
No. 3	229	26.6	24,856	20.0
Total	861	100.0	124,196	100.0
By Type of Mill				
Band	670	77.8	104,201	83.9
Circular	191	22.2	19,995	16.1
Total	861	100.0	124,196	100.0

No. 1 grade: This grade shall include

(a) those logs 12″ to 15″ in diameter that are clear of all visible defects,

(b) those logs 16″ to 23″ in diameter that have at least 3 clear faces or 75 percent of the length clear in one continuous section, and

(c) those logs 24″ and over in diameter that have at least 2 clear faces or 50 percent of the length clear in one continuous section.

Note: In the Clear, Select, and No. 1 grades a center rot or dote of 2″ in logs 12″ to 15″ in diameter, 3″ in logs 16″ to 23″ in diameter, and 4″ in logs 24″ and up will be permitted without degrading the log; however, full deduction in scale must be made for this defect.

No. 2 grade: This grade shall include all logs that are better than a cull and that do not grade as a No. 1 log; minimum diameter 10″.

Woods run grade shall consist of hardwood logs 10″ and up in diameter as produced from the forest, that are better than culls and from which no selection of large-sized or high-quality logs has been made. If any large-sized or high-quality logs have been removed from the run of logs, the remaining logs must be sold at prices no higher than the No. 2 grade prices, if ungraded, or at the applicable grade prices if graded. When any small-sized or low-quality logs have been removed from the run of logs, the remaining logs may still be sold at the woods run price.

A Cull log shall be one where the net board foot scale after deductions have been made for defects is less than 50 percent of the gross scale. Also any log not meeting the length and diameter requirement shall be classed as a cull, unless otherwise specifically provided for.

TABLE C-2. Distribution of Logs by Diameters and Grades.

Log d.i.b. inches	Log grade				Total	
	Prime	No. 1	No. 2	No. 3	Number	Percent
7				2	2	0.23
8				1	1	0.12
9				6	6	0.70
10			18	21	39	4.53
11			29	27	56	6.50
12			54	24	78	9.06
13			55	30	85	9.87
14		49	30	31	110	12.78
15		51	20	14	85	9.87
16	24	36	20	22	102	11.85
17	14	16	12	14	56	6.50
18	16	9	14	11	50	5.80
19	14	10	9	8	41	4.77
20	18	5	10	8	41	4.77
21	10	6	6	3	25	2.90
22	15	5	10	1	31	3.60
23	11	4	3	3	21	2.44
24	4	3	3	2	12	1.39
25	5	3	2		10	1.16
26	1		1		2	0.23
27	2				2	0.23
28	2	1		1	4	0.47
32	1		1		2	0.23
Total	137	198	297	229	861	100.00
Percent	15.9	23.0	34.5	26.6	100.00	

TABLE C-3. *Distribution of Logs by Lengths and Species.*

(Sound logs only)

Log Length[1] (feet)	Species										Total	
	Red Oak	Sugar Maple	Elm	Beech	Poplar	Bass-wood	Hickory	White Oak	Soft Maple	Ash	Number	Percent
6			4								4	0.53
7			2	1							3	0.40
8	7	6	27	9	4	3			1	3	60	7.91
9			1								1	0.13
10	28	27	21	26	22	8	7	6	1	8	154	20.31
11			1								1	0.13
12	59	58	26	36	55	15	8	8	7	3	275	36.30
13	3										3	0.40
14	31	30	21	20	22	4	11	6	3		148	19.51
15		1									1	0.13
16	14	24	22	7	11		5	6			89	11.75
17	1										1	0.13
18	11			1							12	1.58
19											0	0.00
20	3	1			2						6	0.79
Total......	157	147	125	100	116	30	31	26	12	14	758	100.00

[1] Scaling length (minus trimming allowance).

APPENDIX D

TABLES OF LUMBER GRADE RECOVERY

Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Grades

Log Quality Index by Log D.I.B. and Grade

Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Species

TABLE D-1. ***Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Grades.***

Basis: 861 logs; 124 MBM

Log Grade	Lumber Grade	Log diameter inside bark, in inches											All sizes[1]
		8	10	12	14	16	18	20	22	24	26	28	
Prime													
	FAS					43	43	43	43	43	44	48	43
	No. 1C					33	33	33	33	33	36	40	33
	No. 2C					14	9	7	7	8	7	5	7
	No. 3C					10	15	17	17	16	13	7	17
No. 1													
	FAS				20	20	21	22	24	26	29	32	21
	No. 1C				36	38	40	43	46	50	53	57	40
	No. 2C				23	22	19	15	12	9	6	4	19
	No. 3C				21	20	20	20	18	15	12	7	20
No. 2													
	FAS		7	7	7	8	9	11	14	18	22	27	8
	No. 1C		31	33	35	37	40	44	48	51	54	56	36
	No. 2C		30	29	28	26	24	21	17	13	9	6	27
	No. 3C		32	31	30	29	27	24	21	18	15	11	29
No. 3													
	FAS	0	0	0	1	1	2	4	6	9	12	17	1
	No. 1C	14	15	18	23	31	38	44	50	55	60	63	25
	No. 2C	34	37	38	36	32	28	24	20	16	12	8	35
	No. 3C	52	48	44	40	36	32	28	24	20	16	12	39
All Grades													
	FAS	0	5	10	15	19	22	25	28	30	33	36	20
	No. 1C	15	20	25	30	34	37	40	42	44	45	45	35
	No. 2C	40	37	33	28	23	19	15	12	10	8	6	22
	No. 3C	45	38	32	27	24	22	20	18	16	14	13	23

[1] Read from Figure 6 at the d.i.b. corresponding to the volume of the average log in each grade.

TABLE D-2. Average Log Quality Index by Log Diameters and Grades.

Basis: 861 logs; 124 MBM

Log d.i.b. inches	Log grade				
	Prime	No. 1	No. 2	No. 3	All
	Log quality index in per cent				
8				42.4	44.0
10			53.3	43.4	48.9
12			53.9	44.8	53.6
14		63.0	54.5	47.1	58.1
16	76.1	63.6	55.6	49.5	61.5
18	75.1	64.5	57.1	52.2	64.0
20	74.7	65.6	59.5	55.2	66.5
22	74.7	67.6	62.4	58.2	68.8
24	74.9	70.0	65.6	61.5	70.6
26	76.6	72.7	68.8	64.8	72.7
28	80.6	76.0	72.5	68.7	74.4
All sizes[1]	74.7	64.5	55.4	47.7	62.4

[1] Calculated from Figure 6 for the d.i b. corresponding to the volume of the average log in each grade.

TABLE D-3. Average (Curved) Percentage Lumber Grade Recovery by Log Diameters and Species.

Species and Basis	Lumber Grade	Log diameter inside bark in inches									
		10	12	14	16	18	20	22	24	26	28
		Per cent									
Beech: 149 logs 28 MBM	FAS	1	2	2	3	5	9	14	20	27	
	No. 1C	11	17	24	31	39	45	51	55	57	
	No. 2C	24	25	25	24	21	17	13	8	4	
	No. 3C	64	56	49	42	35	29	22	17	12	
White Elm: 130 logs 14 MBM	FAS	3	8	15	23	31	39	46	53		
	No. 1C	15	23	28	29	30	28	27	25		
	No. 2C	31	28	24	21	16	13	9	6		
	No. 3C	51	41	33	27	23	20	18	17		
Sugar Maple: 156 logs 19 MBM	FAS	0	10	17	20	22	25	31	42		
	No 1C	31	27	27	34	41	47	47	41		
	No. 2C	18	23	25	21	16	11	7	4		
	No 3C	51	40	31	25	21	17	15	13		
Red Oak: 167 logs 29 MBM	FAS	7	14	23	31	36	39	41	43	43	43
	No. 1C	21	27	31	32	32	33	33	33	34	36
	No. 2C	24	22	18	15	13	12	12	11	12	11
	No. 3C	48	37	28	22	19	16	14	13	11	10
Yellow Poplar: 118 logs 14 MBM	FAS	4	5	7	8	10	11	13	14		
	No. 1C	21	30	36	43	48	52	54	54		
	No 2C	51	50	48	44	38	34	30	29		
	No. 3C	24	15	9	5	4	3	3	3		

APPENDIX E

TABLES OF MILL TALLY AND OVERRUN

Mill Tally for

Six Indiana Band Mills

Seven Indiana Circular Mills

Overrun from Three Scale Rules in Percent and Board Feet for

Band Mills

Circular Mills

TABLE E-1. Mill Tally in Six Indiana Band Mills.

Log d.i.b. inches	Log length in feet				
	8	10	12	14	16
	Board feet				
8	10	27	43	54	59
10	29	47	63	73	81
12	48	68	82	94	105
14	67	90	102	120	134
16	85	118	134	155	177
18	104	147	176	203	233
20	122	182	228	260	296
22	141	228	285	326	360
24	160	281	341	388	426
26		334	397	452	487
28		388	454	514	550
No. of logs	34	136	264	124	79

TABLE E-2. Mill Tally in Seven Indiana Circular Mills.

Log d.i.b. inches	Log length in feet				
	8	10	12	14	16
	Board feet				
8	23	30	34	39	45
10	36	47	54	62	72
12	49	67	76	86	100
14	62	86	100	113	130
16	75	112	130	147	165
18	88	140	166	189	210
20	101	172	211	242	268
22		206	261	301	333
24		243	316	363	405
26			369	426	482
28			423	488	560
No. of logs	31	37	38	40	28

TABLE E-3. Overrun from Three Scale Rules in Percent and Board Feet for Band Mills.

Basis: 597 logs, 90 MBM

Log d.i.b. inches	Overrun in percent[1]			Overrun in board feet[1]		
	Doyle	D.C.	Int. (¼)	Doyle	D.C.	Int. (¼)
8	..	127	74	36	25	18
10	126	69	36	35	24	16
12	70	39	18	34	23	15
14	43	22	9	33	22	13
16	30	15	6	32	21	11
18	22	13	5	31	20	10
20	18	10	5	30	19	8
22	14	8	4	30	18	7
24	10	6	4	29	17	5
26	7	4	4	28	16	4
28	3	2	4	27	15	2

[1] The two expressions of overrun are not comparable because of conditions imposed on the data in the graphic analyses.

TABLE E-4. Overrun from Three Scale Rules in Percent and Board Feet for Circular Mills.

Basis: 178 logs, 19 MBM

Log d.i.b. inches	Overrun in percent[1]			Overrun in board feet[1]		
	Doyle	D.C.	Int. (¼)	Doyle	D.C.	Int. (¼)
8	..	81	40	29	18	8
10	102	39	21	26	15	6
12	52	20	8	23	12	4
14	28	10	—2	20	9	1
16	15	4	—7	17	6	—1
18	10	1	—6	15	3	—3
20	7	0	—4	12	0	—5
22	5	0	—3	9	—3	—7
24	4	0	—2	6	—6	—9
26	3	0	—1	3	—9	—12
28	2	0	0	0	—12	—14

[1] The two expressions of overrun are not comparable because of conditions imposed on the data in the graphic analyses.

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